ERRATA.

		Instead of	Read this
Page	vi	Valcanoes	Volcanoes
Page	4	Page No. 50	Page No. 51
Page	143	Line 5 :- on	No.
Page	197	Fig. (22)	Fig. (21)
Page	221	Fig. (21)	Fig. (26)
Page	250	Line 21 : the	Be
Page	257	$K.V.A. = \frac{V.A. \cos. \varepsilon}{1000}$	$K.V.A = \frac{V\,A}{1000}$
Page	259	$\sqrt{c^2 + (R \times r)^2}$	$\sqrt{c^2 + (R + r)^2}$
Page	259	$\sqrt{c^2 + (R \times r)^2}$	$\sqrt{c^2 + (R - r)^2}$
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CHAPTER I.

WATER SUPPLY FOR A TOWN

CHAPTER I

WATER SUPPLY FOR A TOWN

Schemes of Water Supply:—The duty of the Engineer is to collect all the information that may prove useful or have a bearing on the question. A thoroughly perfect scheme of water supply can seldom, if ever, be devised within the reasonable limits of outlay. Perfection of design and detail frequently mean large expenditure. Hence, the compromise between the efficiency and economy has generally to be adopted, and the scheme, which possesses fewest defects and entails only a moderate outlay is usually carried out.

The importance of a good water supply to the inhabitants of a town cannot be overrated under any circumstances. The evils arising from the want of such good supply have long been known to scientific men, but like many other branches of useful information, this knowledge should not be treated with indifference and contempt. In short, the large towns, in particular, labour under the drawback of having less pure air, and being more closely inhabited, have as a rule, their systems of water supply and drainage complete and efficient in all respects, as far as possible.

Further, in deciding on the best means of supplying a town with water, the professional advice and guidance is very essential. When an engineer is called in, to advise on the matters of water supply, the consultant is compelled to ground his opinion, and frequently to sign his scheme, on the informations and data put before him. This is frequently the case, where the town or district to be supplied is limited in extent, the various facts bearing on its supply with water are generally collected after months and sometimes years.

Water Supply for a Town:—These are things that have to be taken into consideration before the source of water is decided on for a town supply:—

(1) Quantity and quality of water.
(2) Quantity of water required per head of population.
(3) Conditions of water supply.
(4) Finding the storage capacity of the reservoirs required to be provided, noting the results of observations on rainfalls.
(5) Classification of water works.
(6) Impounding reservoirs.

Let us take Item Nos. 1 & 2:—Generally, the first question to be considered and decided with the supply of water to a town is the total daily quantity required, and is usually stated as so many gallons per head of the population to be supplied, and is easily arrived at, after due inquiry (refer to Page No. 50). The causes of variation of demand are many in numbers. For example, in small towns and villages, the inhabitants will draw their water direct from public taps or fountains and the cost of labour, and even the labour of carrying it to their houses will check even its proper use. In better class towns, like Bombay, etc., the residents will have the water piped in, with a large number of baths, and water closets, etc., all drawing their supply of water from the public mains. The following scale of supply per head for various populations will be found useful:—

Population	Gallons per head per day
500	8
1,000	10
2,000	12
5,000	15
10,000	17
15,000	19
20,000	20
50,000	25
1,00,000	30
2,00,000 & over	35 to 80

In general practice (Indian), for towns of medium extent, the rule is to secure the supply of not less than 20 gallons per head per day, but like most general rule, it is open to many exceptions.

Thus the water per head varies from about 6 gallons to 50 gallons in this country:—

Places.	Gallons per head	Places.	Gallons per head
Calcutta ..	42	Bombay ..	70
Gaya ..	17	Madras ..	35
Agra ..	28	Patna (1935) ..	20
Allahabad ..	25	Bangalore City ..	22
Benares ..	25	" Military Station	20
Cawnpore ..	45	Delhi ..	28
Lucknow ..	20	Karachi ..	35
Muttra ..	26	Poona ..	50

In other countries, the consumption per head is rather larger ranging from 70 gallons per head to 120, and in many cases it is upto 350 gallons (U.S.A.).

The quality of water, is an important inquiry in selecting a mode of supply. It often occurs that a scheme in every other respect suitable must be condemned on this ground. Here, again the engineer must be guided by the chemist. It is not intended to go into the details of water analysis, but let us examine in brief:—To little water add severally:— (1) Silver nitrate—a faint precipitate indicates presence of chloride; (2) Barium chloride—a faint precipitate indicates presence of sulphate. (3) Potasium carbonate—a white precipitate, indicates pre-

sence of calcium, etc. (4) Nessler's Reagent—a brown colouration indicates presence of nitrogenous matters.

Regarding Item No. 3:—If a source of water supply is investigated to discover, whether it is sufficient in quantity, one of three things will always be found:—

(*a*) Minimum supply equals to or is greater than the quantity required. For example, satisfied in case of large lakes, rivers and deep wells.

(*b*) Minimum supply is less than the quantity required, then impounding reservoirs are required, and what storage is necessary to tide over especially dry weather.

(*c*) The average supply is less than the quantity required, then it is absolutely necessary either to search for another source of supply or to find at least additional source of supply to supplement the existing source of supply.

The arrangement, extent and cost of the various features of a waterworks system depends greatly on the nature of its source, its distance from the district to be served, and its elevation above that district.

Regarding Item No. 4:—This question is important, and to illustrate this by an example of a simple case. Let us take a small town to be supplied, as having a population of 1,000 say, and the supply per head being fixed at, say 8 gallons. The total daily demand will then be 8,000 gallons, and this is equal to a flow of 1 cubic foot per minute. Assume that a suitable catchment area of say 50 statute acres with 6″ of rainfall available for town use. The product per acre would then be equal to 21,780 cubic feet. The total quantity available amount to 1,089,000 cu. ft. As before mentioned, the required daily supply is 1 cu. ft. per minute, or 525,600 cu. ft. per annum. These figures show an ample margin. It must be remembered, however,

that for 3 or 4 months in the year, there will be no water available. Hence, during this dry period, the town will be entirely dependent on the storage of the surplus say winter floods. Taking the storage at say 120 days of the required supply, we have a total quantity of water to be stored off is 1,72,800 cu. ft. and for this quantity due accommodation must be provided.

Regarding Item No. 5:—*Let us take first the gravitation work,* and it must consist of:—(1) Either a high level impounding reservoir or a high level intake with a settling tank or reservoir. (2) Filtration plant. (3) Service reservoir for holding enough water to compensate for the inequality of the consumption during 24 hours. (4) A distribution system.

Now, examine from pumping works:—It is consisting of:—(1) A low level intake. (2) One or more settling reservoirs, like Calcutta. (3) Filtration plant. (4) A pumping station with. (5) A high level reservoir near, or within the town, holding enough water to compensate for the inequality of the consumption, during 24 hours. (6) A distribution system.

The two different types of consumptions, as (I) Maximum consumption=Mean consumption ×2 (absolute consumption). (II) Maximum consumption=Mean consumption ×1.5 (ordinary maximum consumption).

General Consideration:—The Standard Practice for the designing of any Water Supply Scheme is to provide for a period of 30 years hence, take the prospective population of that year, as the basis of the scheme. The rate of water supply per head per day differs for different countries, under different circumstances. The average supply for a town, say X, is 35 gallons per head per day, with a summer allowance of 33½ gallons, and the daily supply, say, comes to 7 million gallons.

General Considerations in the Designing of Dams:—Deep foundations and bonding of the structure into rock. The site should have solid rock at a reasonable depth below the ordinary bed level. The structure should never be built over rock of an overlapping nature. Such overlapping rock, even if it be solid, should be removed.

Draw off Arrangements for the Water:—This takes the form of the valve tower, and the valve house. Where their constructions prove prohibitive from the point of view of cost, equally efficient structures of the type, of constant head well can be built for regulating the admission of water into the main line. The necessity of a Grit Chamber should be examined. The Grit Chamber is usually provided below the dam, its chief function is to arrest the heavier mineral matter, as sand, gravel or other grit. This chamber can be avoided, if the course of the river up is sufficiently long and the velocity of water not so great. The provision for increasing the storage in the reservoir, should be made by installations of the type of "Stoney Regulating Shutters," etc.

Earthen Dams:—Design of earthen dam is purely a matter of experience. The ruling factor is the means adopted for preventing water from traversing the dam. This is done by the erection of some impermeable barrier in the substance of the dam. In English practice (including Indian) the impermeable substance is usually clay or clayey earth, but concrete either Portland cement or hydraulic lime or masonry has also been used. The American Engineers usually used "Corewalls," but at present time, concrete, steel plates, etc. are used.

Volcanoes under Earthen Dam:—How P. W. D. Engineers overcame the strange problem provided by a series of mud volcanoes at the toe of the Ashti tank dam in Sholapur district. The Ashti tank has an earthen dam 1,279 ft. long, and 58 ft. high with a

storage capacity of 1,500 million cubic ft. A slip occurred in the dam in 1933, and while repairing it no drains were provided. In the year 1935, another slip occurred, and during the repairs the dam section was further widened. A little later, there was a heavy cloud burst in the reservoir catchment area, and the resultant flood overflowed the waste weir by 2 ft. To remedy this, 16 ft. earthwork from the top of the dam was removed and redone. Owing to the settlement, however, the new work cracked and a slip at the rate of 2 ft. every 16 hours began.

Though an attempt was made to patch it up, the rate of slip steadily increased and several small volcanoes spouting mud appeared at the foot of the dam. This, unexpected phenomenon was found to be due to the obliquely placed 1,000 ft. belt of "Karael" earth which has the peculiar property of turning into a substance of the consistency of crude oil when it is saturated with water. In order to save the dam, drains were plugged and a portion of the additional earthwork removed. This checked the slip, the subsidence decreasing from 4 ft. to 18" a day. Finally, all the additional earthwork was cut away, and the soil laid as a blanket over the volcanoes at the dam toe. After that there has been no further trouble with the dam.

Double Control Outlet Arrangements:—Storage in the book on "Indian Storage Reservoirs" strongly depricates the use of single control outlet valves in this case of the reservoir to water-supply schemes, as they cannot be inspected, until the surface of the water in the reservoir falls below the sill of the sluice or without putting the supply pipes out of use.

Masonry Dam:—The Ogee section adopted is much more strong than is actually required to resist the stresses brought into play. The profile of the dam has been designed as a curve conforming to the course of the overflowing water. This has the

advantage of (*a*) Preventing the formation of a vacuum in the nape, thus retarding the flow; (*b*) Converting the vertical velocity into horizontal velocity. This saves the cost of providing or rather dispensing with the use of apron in front of the dam, as a measure against scouring of the ground.

Atcherley's Theory:—Until 1904, theory of masonry dams was considered to be in a very satisfactory state, and relation between practice and theory was far closer than is usually the case in Engineering.

Escondido and Otay dams are the typical of good American practice.

Multiple Arch Dam in Australia—Length of dam 465 feet:—A small but particularly interesting dam has been completed at Ingleburn, near Sydney, New South Wales. It is the first multiple-arch dam to be constructed by the Metropolitan Water Sewerage and Drainage Board, and represents a noteworthy advance in practice.

The multiple-arch type of dam is one of the most modern forms of construction and utilises to the full the great strength and economy of material that is possible with reinforced concrete arches. In this type of dam, the water pressure is, of course, carried by the series of inclined arches supported by reinforced buttress walls, and in this system of construction both the weight of the dam and the pressure of the water itself are used to render the dam stable on its foundations.

The total length of the dam is 465 ft. consisting of six arches of 40 ft. span. The capacity of the reservoir, which act as a service reservoir for the towns of Liverpool and Campbeltown, is 10,800,000 gallons.

Masonry and Concrete:—Masonry and concrete are protected externally and internally, the first by

plastering, by hand or under pressure by a cement gun. The second method is cementation or pressure grouting. It has been successfully employed in closing off the flow of water through tunnels or leaks in masonry dams, in making doubtful foundations solid and rendering dry and workable flooded pit shaft.

The process consists in injecting through previously drilled holes a mixture of cement and water at a moderate pressure, the result being that successive layers of cement are deposited, the excess water being squeezed through a greater thickness of cement filter, until finally the fissure is completely filled with cement, with just sufficient water to produce the best conditions for good and quick setting.

With metal structures the preservation of metal and the first application of preservating coating is of vital importance. The parts most liable to corrosion and decay are the joints of members and particular attention must be paid to them. Bitumastic enamels and solutions are now widely used and when properly applied give very good results in underwater works and preserve them in a working condition.

Similar devices are appearing in the British practice too. If excellent clay is not available, then it is desirable to make, a dam of black cotton soil and shale. Mr. Strange's specification is a mixture of 1 part of black cotton soil to 1 part of shale. In America, Fanning recommended the following:—

Coarse gravel	59%
Fine gravel	20%
Sand	90%
Clay	12%

To test the mixture by ramming it moist into a bucket, and then ascertaining if it will remain in the bucket, when turned upside-down.

Supply Pipe or Gravitation Line:—The first thing to be done is to study the comparative merits and demerits of the various kinds of materials of which the pipe or conduit is to be made.

Then, the question of velocity of water in the line must be taken into consideration, and sufficient fall must be given, or the size of pipe so determined as to avoid a very low impermissible velocity. If it is a pipe line, jointing can be done by means of spun yarn, and running in molten lead. If the pipe line is at sufficiently great depth from the ground, and also at road crossings, culverts should be provided for.

Chief Functions of the Dam:—The chief functions of the dams are as under:—

(1) To provide a storage against any possible period of extreme draught.

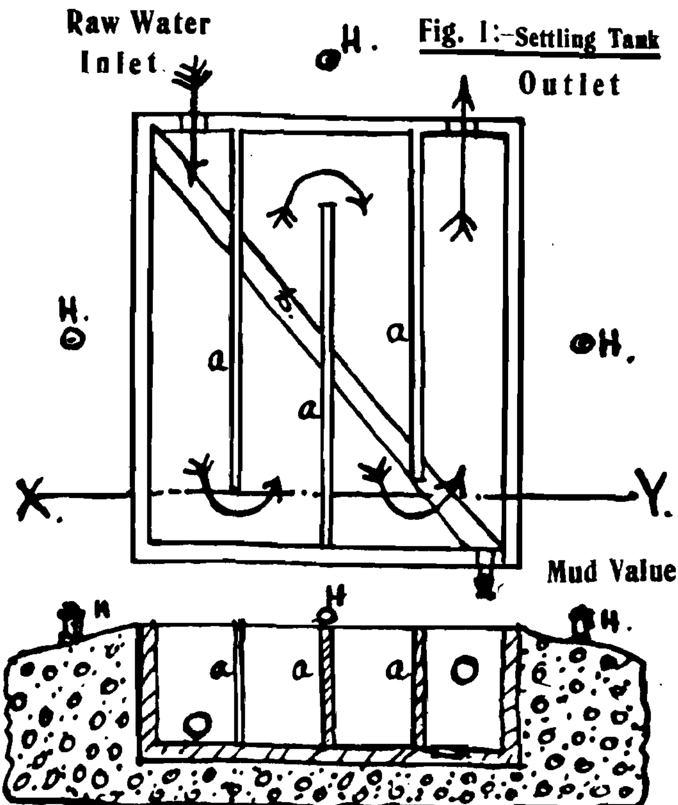
(2) To raise the water level to provide head, which will be one of the considerations, when the difference in level between the city and the source of water supply is not much.

Settling Tanks:—It is provided usually near the source of the water supply, and it has the following functions to perform:—

(1) To remove the lighter material by retaining it for 24 hours with a velocity of 2 inches per minute, when the silt will be deposited by natural settlement. This removal of the silt is absolutely necessary both for the prevention of its deposit in the water-pipe line, in which the velocity developed will be only 1½ ft. per second, and for not over-working the coagulation tanks of the Filter Plant, thereby economising the recurring expense on the coagulant. The design experiments

on the settling tanks had been carried out at Alexandria in the year 1928. As a result, a suitable clarifier design for the water-works was evolved, and in 1935 two large circular clarifiers were constructed for the Siouf Water Works, Alexandria.

Fig. I:—Settling Tank



—Section on XY—

The efficiency obtained with these clarifiers is over 93%, which is a remarkable figure. In view of this high performance in settling suspended materials, and the similar design is recently adopted by the designers of the new Kirkee Water Works, to supply 2-4 million gallons per day to the new High explosive factory. The required water is drawn from the Mutha Right Bank Canal, near the Empress Garden.

Impounding Reservoirs:—The most important Water Supply in India, derived from an Impounding Reservoir is that of Bombay. A very large reservoir supplies is that of Hyderabad, Deccan, and also provides water for irrigation. Profile of the dam has been designed, such that the storage capacity of the reservoir may be increased by holding 8 ft. more of water, without, however, any additional increase in area of the submersion by the installation of Stoney's Regulating Gates, if and when the need for a large Storage is felt, in future.

Storage Reservoirs:—These should be capable of holding:—

120 days' supply in rainy districts.
250 days' supply in drier districts (Molesworth).
250 days, when annual rainfall is 30″ (Williams).
120 to 160 days (Neville).
300 days, when annual rainfall is 18″.

Service tanks:—Mr. Hawksley's formula for storage is largely used by water works schemes designers.

$C = \dfrac{1000}{\sqrt{r}}$; where C = number of days' supply to be stored.

r = average annual rainfall during 3 consecutive dry years.
= 0.8 mean annual rainfall.

The standard practice (Macpherson) for designing the service tanks, is that it should contain 3 to 7 days' supply.

Practical Hints:—While dealing with the problem of Water Supply Schemes, the following details are essential, from the Water Supply Engineering standpoint, as under:—

(1) Sources of Supply
(2) Impounding Reservoirs
(3) Service Reservoirs
(4) Settling Tanks
(5) Filters
(6) Pumps (as the case may be)
(7) Distributing Systems.

These are given in the tabular form, as under on Page 16.

Estimating Supply:—For the purpose of estimating the supply available, the usual custom is to consider the run off only from the surface of the watershed, and the rain falling directly into the tank. An example of the form of calculation required is given as under:—

Suppose that it is desired to give a small town of say, 5,000 inhabitants, a water supply entirely through *"street standpost."* For this a total allowance of 5 gallons per head per day will be sufficient, that is 25,000 gallons per day. The source of water supply is to be a tank, from which the water will be pumped and filtered. The first thing to decide is, what catchment area is necessary to drain into the tank, to give the required supply. The rainfall records must be examined (at the town to be supplied or somewhere in the neighbourhood), to ascertain what the mean rainfall is. Assume that this is 60", and that in a dry year, it may be as little as 40". Of the rain that

Sources of Supply.	Impounding Reservoirs.	Service Reservoirs.	Settling Tanks.	Filters.	Pumps.	Distributing System.
(1) Rivers and Streams (Liable to sewage Pollution).	Not Necessary	Necessary	Necessary	Absolutely Necessary	Necessary	Necessary
(2) Natural Lakes.	Not Necessary	Necessary	Not Necessary	Necessary	Necessary	Necessary
(3) Artificial Lakes.	Necessary	Necessary	Not Necessary	Necessary	Necessary	Necessary
(4) Wells	Not Necessary	Necessary	Not Necessary	Necessary	Necessary	Necessary
(5) Boreholes and Infiltration Galleries.	Not Necessary	Necessary	*Not* Necessary	*Not* Necessary	Necessary	Necessary

falls, the larger portion of it is absorbed into the ground, or is evaporated. In this case, say, that it is estimated that 60 per cent of the water which falls on the ground, disappears in this fashion, this is equivalent to 24″ of rain, leaving only 16″ of rain per annum available for the town supply in a very dry year. It is required to provide 25,000 gallons per day, and to this must be added the water lost by evaporation from the tanks, or by absorption through the sides. The amount so lost depends on the size and shape of the tank, and the nature of the ground. In this instance, assume to take it at 10,000 gallons per day. The area of ground draining into the tank must, therefore, be large enough, with a run off of 16″ per annum, to give an average of 35,000 gallons per day, throughout the year. If

A=area in sq. ft., then $\frac{A \times 16}{12 \times 365} = \frac{35{,}000}{6.25.}$

Therefore A=1,533,000 sq. ft. **or 35 acres nearly.**

The capacity of tank depends upon the amount of Rainfall, and its distribution throughout the year. In this case, it would probably require to hold about 10,000,000 gallons or 1,600,000 cu. ft. A convenient size works out to is 400′×250′×16′.

Note:—The water supply of the aforesaid description is a suitable one for a small town, where there are no large rivers, and a good supply cannot be obtained from the wells or springs conveniently near at hand.

One of the living examples of the aforesaid description is Satkhira Water Works. It has a water supply of 16,000 gallons per day from a tank. Water is pumped by crude oil engine, and force pumps, through a "Mather and Platt" pressure mechanical filter to an overhead tank, from which, water is distributed throughout the town by the Gravitation Scheme.

One more important point to be considered, in the maintenance of such a water-works, is that, the percentage of rainfall discharging into the tank can be considerably increased, by keeping the grass of the water shed, as short as possible, maintaining the main discharge channels into the tank clear, and cutting small branch drains wherever required.

Underground Water Resources:—Capt. Leonard, Munn, M.E. (Camborne), etc., a special officer in charge of Well Sinking Dept., of H. E. H. the Nizam Government, in his paper "Underground Water Resources" of Hyderabad State, and notes on "Well Sinking," who, in the course of his preparatory note, states that, as in the Hyderabad State, whose revenue is nearly wholly dependent on Agriculture, with a climate practically rainless for 5 or 6 months out of the twelve. He has attempted to describe the mode of occurrence of water in the rocks of the State. He refers to the Raichur District, as an outstanding example, and the rainfall curve of Raichur Doab, which he has drawn from the old Government records, offers valuable data. The views of Capt. Munn's on "Water Finding" will probably find wide acceptance amongst Hydrologists in the near future. After emphasising the prime requisite for a water finder, namely the gifts of observation and deduction, Capt. Munn remarks that *"the scientific imagination, and the habit of considering the distribution of rocks in 3 dimensions are essential to a successful water finder."* His tips for location of underground water based on sound common sense, and keen observation, constitute a safe and practical guide for those in quest of water. His paper on Well Sinking may be said to be unique, as no other source of information dealing with the problems on well sinking in South India, etc., so exhaustively exists. As Special Officer in charge of Well Sinking Dept., Capt. Munn had to face many practical problems from day to day. The results of his researches

applied and found successful, mind, in the rainless Raichur Doab, constitute an important contribution to the subject of Practical Water Supply. In the concluding paragraphs, the method of testing the yield of wells, the problem of village water supply, and of emergency wells, of devices to increase the yield of wells by means of lateral tunnels, etc., the advantages of constructing infiltration galleries, and sub-surface dams, where conditions are favourable, are described in detail.

The outline sketch is necessary to explain this example with the form of Calculation required and is given as under:—The authors have designed the Water Supply Scheme for a proposed Residential Parsee Colony, in the Kolaba District, and the same scheme is kept in abeyance for the time being, and read thus: After consideration of all available Sources of Water Supply, it proposed to decide to draw Water Supplies, for both potable and process water, from the seven existing wells, and accordingly to instal the treatment plant necessitated by the condition of the Source. The pumps are centrifugal with 1,450 revolutions per minute, giving 60,000 gallons per hour, against an approximate head of 36 ft. and *they are to be controlled electrically, in common with the pumps in the filter house, by the level of water in the Service Reservoir.* The delivery from the in-take pumps through two 12" diameter pipe is controlled by a flow controller, located in each of the Dorr Clarifier Tank of Water Works. These are necessitated by the fluctuating levels of the wells, and the need for equating the in-take pump delivery to the demands by the clarified and portable water pumps. Recorders give the flows through the both mains, and the total. *The Dorr Clarifier Tank, a somewhat unusual feature in Indian Water Works,* has been proposed by the Authors to be provided, on account of the large amount of solids, etc., supposed to be in suspension

in the well water. From it, the clarified water flows over a weir, into the collecting tank, and at the end, there is a draw off supply of clarified industrial water for certain factories for future to be given at the maximum pressure of 30 lbs. per sq. inch, delivery being effected by a 16 H.P. centrifugal pump in conjunction with a small 1½" house tank centrifugal pump, giving 1,000 gallons per hour. *The necessity of a storage tank for this supply is eliminated by the provision of automatic pressure, actuated electric switch gear, which for small demands actuates the small pump, and throws in the large pump, when occasion arises.* For providing potable water, three or four gravity air cleaned filters, the authors proposed to be provided, giving a total flow of 55,000 gallons per hour to the clear water tank, whence delivery to the close reservoir, situated on the adjacent hillock or elevated reservoir, is effected by two high lift centrifugal pumps, each capable of 60,000 gallons per hour, and driven by 80 H.P. Protected Type Slip Ring Motors. The PH value of the filtered water is constantly mechanically recorded. *Immediately before the pumps, the chlorination is to be carried out by means of an automatic chlorine residual content controller, which is new to this country.* A residual chlorine recorder is also being proposed to be provided by arranging with the Company. The storage reservoir will have two compartments of 2,50,000 gallons capacity each, equivalent to 10 hours' storage for the full capacity of the filters. From the reservoir, the water will be distributed through a system of Water Mains of Cast Iron or Hume Pipe. To increase the yields of the 7 wells, adits or headings or tunnels will have to be driven at the bottom, and the authors proposed, further, to connect a series of wells to concentrate the pumping arrangements in one well only. This would certainly be an economical proposal.

CAWNPORE WATER WORKS

Sources of Supply:—Cawnpore Water Works possess the very rare advantage of two alternative sources of raw water supply, *viz*., the Ganges and the Lower Ganges Canal. The first source tapped was the Ganges but with years advancing the river was found to be rapidly changing its course away from Cawnpore and the second alternative source from the Canal was then utilised using the supply from River only during the rains.

Re-Organisation Scheme

Raw Water Station at Bhairon Ghat:—In 1937, when the supply of filtered water was 9 m.g. a day, the supply of water to the city was found to be inadequate due to the increase in population and Reorganisation Scheme was drawn up and executed, completing in 1942. In this reorganisation scheme the supply was augmented from 9 to 15 million gallons a day using the river as the main source of raw water. As the river course had changed away from Cawnpore, power dredging has been successfully adopted to dredge out a channel to bring the raw water at the Unfiltered Water Pumping Station at Bhairon Ghat where modern electric motor driven pumps capable of pumping 16½ m.g.d. of raw water with 33.3% standby and room for future extension have been provided.

Head Work at Benajhabar:—There are two sets of filters at Benajhabar, *viz*., 9" Slow Sand having a bed of fine white Ganges Sand over 9" gravels on perforated tiles and Degrossieurs with 12 Puech Chabal filters having 30" bed of coarse Jamna sand on 6" gravels and perforated tiles. The latter were installed many years back with the object of increasing filtering capacity, but as they failed in their object, they were before the Reorganisation Scheme, being run in series. For increasing the filtering capacity in the reorganisation scheme, it was decided to utilise the

Puech Chabal Filters for the purpose for which they were intended and instead of constructing new Filters, the two sets of filters were designed to run in parallel. In order to achieve the above, mechanical coagulant (alum) mixing and silt cleaning mechanism have been installed. The plant now in use at Benajhabar have been supplied and constructed by M/s. Paterson Engineering Co. and it removes 95% silt with a dose of Alumina Ferric varying from 2.25 to 1 grain to a gallon according to the turbidity of water. After the addition of coagulant the raw water is let into the flocculating chamber where the mechanical mixing is effected by Flocculator wheels and the water then passes into the Clarifying Chamber where the silt deposits at the bottom. The deposited silt is next cleaned off by hydrostatic pressure. From the flocculating and clarifying Tank the water is then passed on to the two sets of filters. Effluent from the Final Filters is treated with Ammonia and Chlorine before it reaches Clear Water Reservoirs. Dose of Chlorine varies between .4 to .2 p.p.m. according to the quality of water.

The smallest diameter that can be ground should have its centre at the same height as that of the grinding and control of wheels.

Distribution System:—In order to reduce the waste to a minimum, a 24 hours' supply with 60 gallons per head per day has been provided for Cawnpore on a regional control basis for which the whole of the city has been divided into the Zones having equal population in each zone. For each zone, a reservoir has been constructed with adjoining pump house having three high lift pump each capable of pumping 700 gallons per minute against a head of 80 ft. and one low lift pump pumping 350 gallons per minute against a head of 45 ft.

Filtered water from Benajhabar is pumped into the zone reservoirs at an uniform rate and the zone

feeding mains are supplied from the zone pumps. The running of the Zone pumps is automatically governed by water lével in the reservoir, pressure in the main, and time switches, so that with the increased demand all the three high lift pumps are simultaneously put into operation and again with the reduction of demand the number, pumps in operation, are put out of running automatically. In the night time low lift pumps are run to keep the mains under pressure.

Further Extension:—With the rapid development of war industries at Cawnpore, the population of Cawnpore was found to have doubled itself with the ...al consequence of shortage of supply even after ...ompletion of the reorganisation scheme. *The ...g system adopted in the Reorganisation is very ...ble and could be easily extended in peace time to ... the requirements of the increased population.* ... number of filtering units at the Head Works ...being increased to meet the increased demand ...the increased quantity of filtered water will be ...eyed to the city by the old pumps at Benajhabar.

Just to get an idea as to how any particular Water Works stands as regards the initial capital cost, consumption of water per head, fuel consumption, income and expenditure, etc., the following statistics of the five big Municipalities of the United Provinces have been given with the hope of its being useful to Water Works Engineers to enable them to compare the figures with those of their own. It is essential to note that the five big Municipalities of the United Provinces have double pumping, that is, water is pumped from the Intake Station to the Filtered Station and again after filtration to city.

Statement showing initial capital cost, details of income and expenditure for Water Works in the United Provinces for the year 1936-37 as shown in the Superintending Engineer, Public Health Department's (United Provinces) Annual Report ending the 31st March, 1937.

Item Nos.	Particulars.	Agra.	Allahabad.	Benares.	Cawnpore.	Lucknow.
1	Description of plant	Oil engine, steam power and electric motors.	Steam power, oil engine and electric motors.	Steam power, and electric motors.	Steam power, and electric motors.	Electric motors.
2	Initial capital cost in Rupees in lakhs	11·71	16·24	25·62	14·45	15·16
3	Total cost of works in lakhs	36·78	45·86	45·87	38·33	68·08
4	Number of inhabitants drawing their supply from mains.	229,764	183,914	205,315	243,755	194,438
5	Hours of supply daily	10·17	15·00	16·05	18·60	17·00
6	Quantity supplied during year in millions Gallons.	1,468,130	2,109,663	2,914,784	3,471,050	3.220,889
7	Total water horse-power hours per annum in millions.	1·31	2·63	2·49	2·33	3·31

8 Average supply per he[illegible]		31·43	38·89	39·01	45·38
9 Total lift (average) Feet	176·79	246·40	169·30	132·64	203·47
10 Quantity supplied during the year in millions. Foot gallons.	259,551	519·821	493,473	460,400	655,354
11 Fuel or electricity consumed. Tons'Units..	490,599 tons.	3,196,556 units.	3,056,012 units.	2,817,698 units·	4,084,759 units.
12 Fuel or electricity consumption per million foot gallons. Lbs./Units,	42·34 lbs.	6·15 units.	6·19 units.	6·12 units.	6·23 units.
13 Cost of fuel or electricity per ton/unit. Rupees/Annas.	Average Rs. 14·18 per ton.	As. 0·809 per unit.	As. 0·742 per unit.	As. 0·660 per unit.	As. 0·772 per unit.
14 Cost of establishment per *million foot* gallons. Annas.	3·78	2·49	2·67	5·14	3·30
15 Cost of fuel of electric energy per million foot gallons. Annas.	4·94	5·12	4·66	4·28	5·28
16 Cost of oil and waste per million foot gallons. Annas.	0·18	0·03	0·04	0·03	0·02
17 Cost of repairs to machinery per million foot gallons. Annas.	0·11	0·05	0·07	0·16	0·02

Item Nos.	Partrculars	Agra.	Allahabad.	Benares	Cawnpore	Lucknow.
18	Cost of other charges per million foot gallons. Annas.	2·45	0·89	0·08	4·31	2·00
19	Total charges per million foot gallons. Annas.	11·46	8·58	8·42	13·87	10·62
20	Maintenance charges per thousand gallons supplied. Annas.	2·03	2·12	1·42	1·84	2·16
21	Interest and sinking fund charges per thousand gallons supplied. Annas.	0·70	1·05	1·29	1·11	0·70
22	Total (maintenance and interest and sinking fund) per thousand gallons supplied. Annas	2·73	3·17	2·71	2.95	2·86
23	Maintenance charges in thousands Rupees.	185·94	278·68	259·71	399·20	435·13
24	Interest and sinking fund charges in thousands.	64·75	138·83	234·38	241·46	140·01
25	Total income in thousands. Rupees ..	329·21	498·50	343·45	701·30	641·53
26	Profit or loss on maintenance in thousands. Rupees.	143·27	219·82	83·74	302·10	206·40

27 Total number of connections	6,160	8,447	17,804	16,175	15,825
28 Water-tax on assessment	2,05,991	3,32,348	2,81,331	4,50,384	4,36,224
29 Sale of water meter rent and other charges.	1,16,115	1,30,156	30,181	1,99,775	1,12,301
30 Total income. excluding cost of water used for Municipal purposes.	3,22,106	4,62,504	3,11,519	6,80,159	3,68,525
31 Receipt for 1000 gallons on total income in Annas.	3·59	3·78	1·88	3·23	3·19
32 Maintenance charges per connection in Rupees.	30·18	32·99	14·58	24·68	27·49
33 Interest and Sinking Fund charges per connection in Rupees.	10·51	16·43	13·16	14·92	8·84
34 Income per connection in Rupees ..	52·29	54·75	17·49	32·04	35·92

Analysis of pumping costs, etc. of various waterworks in the United Provinces during the year 1936-37 as shown in the Superintending Engineer, Public Health Department's (United Provinces) Annual Report ending the 31st March, 1937.

Item Nos.	Particulars.	Agra.	Allahabad.	Benares.	Cawnpore.	Lucknow.
35	Fuel (coal & oil) or electricity consumed per annum. Tons/Units.	Coal 3,727·70 tons. Fuel oil 57·07 tons. Electricity 170,499 units.	.. .. Electricity 3,196,556 units.	.. .. Electricity 3,056,012 units.	.. .. Electricity 2,817,698 units.	.. .. Electricity 4,084,759 units.
36	Cost of fuel or electricity per ton/unit. Rs./As.	Coal Rs. 12·80 Per ton. Fuel oil Rs. 104·12 Per ton. Electricity As. 1·500 Per unit.	Electricity As. 0·807 Per unit.	Electricity As. 0·742 Per unit.	Electricity As. 0·660 Per unit.	Electricity As. 0·772 Per unit

37 Estimated number of water horse-power hour per annum.	1,310,862	2,625,358	2,492,288	1,325,258	3,309,870
38 Consumption of fuel or electricity per water horse-power hour. Lbs/Units.	8·38 lbs,	1·22 units	1·23 units	·21 units	1·23 units
39 Cost per water horse-power hour. Annas.					
(a) Fuel	0·979	1·013	0·924	0·837	1·045
(b) Lubricants	0.033	0·006	0·005	0·005	0·005
(c) Labour	0·290	0·173	0·120	0·320	0·172
(d) Stores	0·056	0·011	0·020	0·010	0·024
(e) Repairs and maintenance ..	0·022	0·010	0·015	0·032	0·004
Total Annas ..	1·379	1·213	1·084	1·204	1·250
40 Total cost per head per annum. Annas ..	18·03	36·88	42·00	45·08	52·69

BENARES WATER WORKS

The Water Works consists of the Unfiltered (Intake) and Filtered Pumping Stations. The Intake Station is situated on the bank of the river Ganges. next to the sacred Tulsi Ghat. Worthington-Simpson High Duty Vertical Engine was installed, having a capacity of 8.333 gallons per minute. There are only two such Engines in India. The Babcock and Wilcox Boilers were fitted with Mechanical Strokers in the same year. In 1929, two additional Worthington-Simpson Centrifugal Pumps of Vertical Spindles were installed, directly coupled to A.C. Motors of 340 B.H.P., 3,300 Volts, 50 Cycles, to supply 6,000 gallons each at 115 feet head.

Water is pumped from the Unfiltered Station through two Rising Mains, each of 24″ diameter and 4,700 feet in length, and through the Recording-Weir to the Settling tanks.

There are 3 Settling tanks, each 409′×258′× 18′ deep, and of 87,22,146 gallns capacity. In the rainy season the water is very turbid, when Alumina-ferric is administered for settling down the turbidity, and the tanks are used in series. From Tank, the water goes to the Slow Sand Filters through the Drainer.

There are at present twelve filters, and two more are intended to be constructed in the ensuing year.

Each filter is 200′×100′ to supply one million gallons in 24 hours, or say 50 gallons per sq. ft.

From the filters, the water runs to the two underground Clear-Water Reservoirs, each 178.5′×148.5′× 12′ of 18,54,068 gallons capacity, where the water is chlorinated.

The Filtered Water Works consists of two sets of Beam Engines, each of 7,500 gallons capacity, per minute. These Beam Engines were erected in 1892, and are still in excellent condition.

In 1929, 3 sets of Worthington-Simpson Horizontal Volts, 50 Cycles, each of 3,600 gallons capacity per Centrifugal Pumps were installed, two of which are directly coupled to G.E.C. Motors of 245 B.H.P., 3,300 minute, against the total head of 135′, and one of 5,400 gallons capacity, per minute, directly coupled to a Motor of 365 B.H.P.

There is one High-level Reservoir of 60′ diameter, 15′ deep, of 256,000 gallons capacity. The height of this tank is only 60′ and due to the abnormal increase in the number of water connections, much *dfficulty is being experienced in maintaining the head; hence, the water is pumped direct into the Service-Mains,* the High level Reservoir being used in cases of emergencies, such as in cases of fire at night when pumping is stopped.

In Benares, the variation of levels, between the lowest and the highest, is of 68′ and, as stated before that this Water Works was originally designed for four million gallons capacity only, the daily supply, these days, has comparatively become double, due to which great trouble was experienced in the High level localities. To remedy it, as far as practicable, the city has been divided into two parts, and the water is pumped into the two separate Mains, for the High Zone and the Low Zone. Certain highest levels of the Pacca Mahal of the city were inconvenienced for want of water, but the Board was not in a position to spend a lot over the Water Mains (*which were laid 48 years back, and were originally designed to supply only half the capacity of what is being supplied at present*), *hence much trouble had to be experienced. Consequently, two Booster Pumps have been fitted in the city at Godowlia to increase the pressure for the High levels minimising the trouble thereby.*

In the Water Works, there are two Service Mains of 30″ diameter each, as well as one of 15″, one of

10″ and one of 7″ diameter; and, in the different parts of the city, the Mains vary from 30″ to 3″. The total length of the Service Mains is about 72 miles.

The entire plant is being run with electricity, taken from the Benares Electric Light and Power Company, and the Steam Plants are being maintained as standby, but have been kept in such a condition that, in the case of an emergency, they can be run within only a few hours.

Small Unfiltered Water-Mains have been laid on the main roads for their watering. For this, there are separate Electric-driven Centrifugal Pumps, running against 225′ head. These Pumps have been fitted at both the Filtered and Unfiltered Stations and near the Burna Bridge, in the Cantonment, whereby there has been much saving of filtered water.

This Water Works has got a well-equipped Workshop, fitted with Foundry, capable of doing castings up to 5 tons. Apart from doing the Municipal works, it also undertakes to carry out outside works.

Certain important figures are given below, for the year ending the 31st March, 1938.

13.25 was the daily average pumping hours of the Filtered Station and the pressure, maintained on the Pumps, was 85.16 feet.

The consumption of the filtered water during the year was 2,86,69,97,217 gallons.

The daily average consumption during the year was 78,54,787 gallons.

The average consumption per head per day of population was 38.26 gallons.

The net cost of maintenance was Rs. 2,39,584, and the same per thousand gallons was 1.42 annas, and per each water connection it was Rs. 14.58.

Kolar Water Supply (Mysore):—A cast iron pipe has been provided from the Ammarahalli tank

to the filters (i.e. alum plant and pressure filters). As the water reaches the mixing chamber, it gets a dose of alum, and then passes through a long duct with baffle walls to the settling tanks of a total capacity of 450,000 gallons, is based on 3 days' supply principle thus giving ample time for sedimentation. The water is drawn from this settling tanks to a suction pit, and then pumped through 3 pressure filters, each of 2,700 gallons per hour capacity. The filtered water is collected into an elevated tank, and a low level reservoir, having capacities of 40,000 gallons and 180,000 gallons respectively. This installation provides for a supply of 10 gallons per head per day for the population of about 16,000 in the town.

Bhagalpur Water Works:—Sir Maurice Hallet, Governor of Bihar, on 13-1-1938 opened this water works; it marked two events of special interest to this town, as the first being the celebration of the golden jubilee of water works, and secondly the completion of the modern rapid gravity filters to purify the whole of the water obtained from the river Ganges. Here, seven sets of electrically driven pumps have been installed, three elevated service reservoirs with the distribution system, rearranged, and all the house connections metered with new filters at Borari (a intake well). This well has been designed so that the length of the channel from the river to the unfiltered water pumps will be 200 ft., less than with the existing arrangement, and so effect a considerable saving in the cost of keeping the channel open during the dry season. The Paterson rapid gravity filters with the latest type of automatic control are designed to deal with one million gallons in 16 hours, and to produce an effluent of the highest standard of bacteriological purity, and they are housed in an earthquake-proof building of R.C.C. framework with brick panelling, and carrying on the roof, a R.C.C. tank of 25,000 gallons of water for washing the filters, when needed.

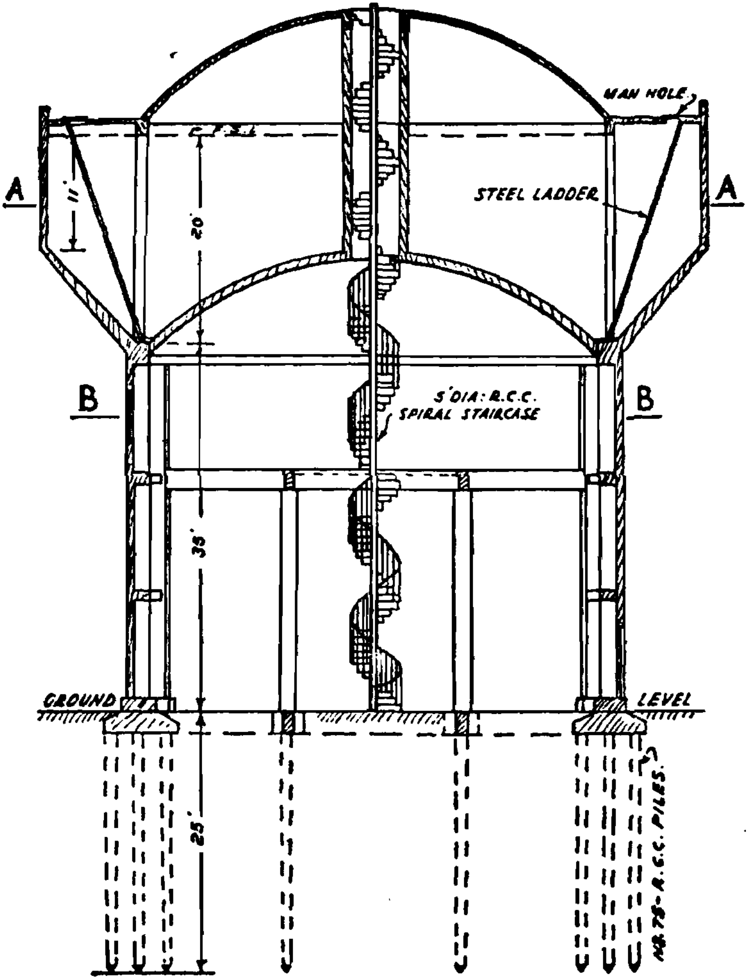
Karachi Water Works:—Mr. H. D. Howell, M.I.C.E. Superintending Engineer, Public Health Engineering Service of Punjab, was consulted, and he submitted his conclusions advising the Corporation, the taking of immediate steps for a survey of the Indus scheme, and begin borings across the Malir river near the dak bungalow, to find impervious strata to construct a cross gallery to intercept water flowing into the sea, thus increasing the supply from 8,000,000 to 12,000,000 gallons a day. Mr. Howell was not in favour of constructions of a diaphram at the Dumlotte gorge, nor he suggested a sub-soil water scheme for flush purposes, on ground of cost and danger to the dual system pipes. Water supplied to Karachi is mostly drawn from 7 deep wells and infiltration gallery in the river bed. It is therefore wholesome and very palatable. It also passes through the natural process of filtration through the sandy soil, before it is pumped up into wells. The intermittent system of water supply affords time for the water to settle down in the reservoirs, before being distributed. Therefore, there is little chance of dissolved or suspended inorganic or organic matter remaining in it. The Paterson's Chlorination plant, however, forms part of the water works to remove bacteriological impurities.

Tank Supported By Cylindrical Concrete Column

A water reservoir of unique design has been constructed in Hyderabad (Sind). The whole structure is of reinforced cement concrete, the tank resting on a huge cylindrical column. The reservoir itself is of an unorthodox shape: the outer wall of the reservoir is cylindrical and rests on cantilever frustum of a cone; the roof and bottom of the reservoir are dome-shaped like inverted bowls. This extraordinary design, it is claimed, will increase the capacity of the tank. See Fig. (2) on page (35).

The new structure will contain the third water storage tank of the city. There are already two, one

WATER RESERVOIR OF UNIQUE DESIGN FOR HYDERABAD (Sind)



CROSS SECTION

Fig. 2.

a high service reservoir and the other a low service tank. The existing tanks are held to be inadequate for the city's needs; at all events, there is no safety margin. The city's water supply system is itself a complicated affair and will be dealt with later. The peculiar and difficult nature of the water supply arrangements has necessitated the provision of a new reservoir. During the rush hours of the morning the high level tank's capacity is good enough only for half an hour, while the low level tank is adequate for eight hours' drain. If anything happens to the pumps and the existing reservoirs become empty, the city will have to go without water. Hence the need for a new reservoir. Its capacity is 300,000 gallons, and the construction has cost about Rs. 50,000/-.

The height of the new tower is 65 feet, the pile foundation going down 25 feet below the earth surface. 75 R.C.C. piles have been used for purposes of foundation. The cylindrical column is 35 feet in height and about 50 feet in diameter. The column supports a dome-like structure which forms the bottom of the reservoir. This dome, whose edge rests on the top of the cylindrical column, is further supported by four R.C.C. cross beams running from edge to edge of the cylinder and propped by vertical R.C.C. column inside the hollow of the cylinder.

From the top of the cylindrical column rises at an angle of 45 degrees the cantilever frustum of a cone, 12 feet in length, to act as the support for another and wider cylindrical column, 11 feet in height, forming the circular wall of the tank, which is 64 feet in diameter at the top. This wall is surmounted by another dome, the roof of the reservoir. The distance between the bases of the two domes is 20 feet.

An R.C.C. spiral staircase, five feet in diameter, runs from the ground level right through the centre of the reservoir to the top of the upper dome; there

is no other approach to the reservoir. There are manholes in the circular verandah on top of the reservoir at the base of the upper dome. From the spiral staircase landing at the summit, attendants climb down the rungs of steel staircases skirting the roof to the verandah running round the base and then through the manholes to the case of the tank for cleaning and repairing purposes.

The new reservoir is built very near the two old ones, all three on top of a low hill within a fort of brick and mortar built by the Mirs of Sind. The existing low level reservoir is an open tank in the ground while the present water tower is about 90 feet high and has a capacity of 100,000 gallons.

Until three years ago a steam-driven pump installed on the bank of the river Indus—the only source of water supply for the city—used to bale out water from the river into eight settling tanks alongside the river. From here, the water flowed by gravitation through masonry aqueducts to an underground reservoir at the foot of the fort. Another pumping plant here lifted the water to the top of the hill into the two old reservoirs, whence the city was supplied through pipes.

Madras Water Works:—The Poondi reservoir in Chingleput district, marks a significant land-mark in the history of Madras Water supply. It is designed for the storage of water for an anticipated population of one million citizens and will serve as a perennial source of supply to Red Hills Lake, from which Madras has been receiving its water. The Red Hills project was conceived as far back as 1866, as a combined irrigation and water-supply scheme, but the consumption of water in Madras increased from 2½ million gallons in 1878, to 24 million gallons a day in 1936. Then, the need for an additional source of supply began to be felt. Mr. Velayada Mudaliar, Civil Engineer, suggested to the Corporation of Madras the possibility of constructing a dam

to impound the considerable volume of water, which was, otherwise, discharged into the sea. This was the genesis of the Poondi scheme. This new Poondi reservoir in addition to being a standby in case of failure of monsoon, provided for adequate storage of water for a population of one million at 30 gallons per head per day. Even with the completion of Poondi reservoir, it cannot be said that the water supply of the city has become perfect, and further works have yet to be executed, and is the existing distribution, i.e. pipes from Red Hills to Kilpauk pumping station can only carry about 24 million gallons per day. The system of slow sand filtration will have to be replaced by the rapid mechanical filters, with a separate branch main to serve the city is absolutely necessary. This is all about overhauling and remodelling of the city's water supply distribution.

Hyderabad (Dn.) Water Supply:—The Water Supply to City of Hyderabad and Suburbs is drawn from the Osmansagar and Himayatsagar Lakes situated about 12 miles above the city. These lakes are constructed across the two arms of the Musi River which flows through the Capital. Prior to the construction of these reservoirs water supply used to be drawn from two other small lakes in the neighbourhood, *viz.*, the Husseinsagar and Mir Alum. The Mir Alum is a picturesque lake with a multiple arch dam.

Prior to the construction of the Reservoirs, the City was exposed to the risks of floods. The floods of 1908 caused considerable loss of life and property to the City. It was therefore necessary to construct two Reservoirs to control the floods and to store the water for the use of population which had outgrown the capacity of the two small lakes, the former sources of water supply.

The following are the principal features of the Osmansagar and Himayatsagar Reservoirs. The

Osmansagar Lake is named after H. E. H. The Nizam, while Himayatsagar is named after the Crown Prince, H. H. Prince of Berar:

Data	Osmansagar	Himayatsagar
1. Catchment area	285.00 Sq. Miles	505.00 Sq. Miles
2. Total Length of Dam	6300 Ft.	7400 Ft.
3. F. T. L.	R. L. 1805	R. L. 1774.
4. Total Capacity at F. T. L.	10768 M. Cft.	7080 M. Cft.
5. Flood moderating capacity	6829 M. Cft.	3274 M. Cf.t
6. Maximum Height of Dam above foundation	118 Ft.	111 Ft.
7. Water spread area at M. W. L.	16.22 Sq. Mile	12.6 Sq. Mile
8. Maximum Depth of Water above bed level of River & below F. T. L.	104 Ft.	84 Ft.
9. Flood gates	15 x 6 x 40	17 x 15 x 20
10. Maximum dis-charge through Flood gates	25,000 Cusecs	75,000 Cusecs
11. Cu. Ft. of Masonry	76,27,171 C. Ft.	94,56,700 C. Ft.

From Osmansagar water is carried through a conduit of masonry 9 miles long to the Filters at Asif Nagar. The conduit is capable of carrying 21 Million Gallons a day. The Asifnagar filters comprise of 12 Filters of Paterson's Rapid Gravity Type and 5 Candy Filters. These sets are capable of yielding 14 Million Gallons of pure chlorinated water supply per day. The distribution system is about 200 miles in length and has been designed to provide for a consumption of 45 gallons per head per day.

The Hyderabad State Water Works which were constituted at a cost of nearly Rs. 127/- lakhs have been subjected to progressive remodelling to serve the expansion of the population as well as the extension of the City Area.

WATER SUPPLY IN BHOPAL

Sources of Supply:—Bhopal lies in a valley, the greater portion of the City lying on the Hill sides at the East end of the Upper Lake. The Upper Lake has a surface area of 2.32 square miles with a top water level of 1656.7 R. L. and an approximate normal low water level of about 1648.0 R. L. before the rains. Due to the shelving nature of the sides of the valley there is rapid reduction in the surface of the Lake with each foot of fall in water level. For the reason stated regarding slopes the capacity of upper lake between the levels stated has been calculated at 500,000,000 cubic feet or say about 3,125,000,000 gallons.

The Lower Lake has a surface area of 0.27 square mile and a top water level of approximately 1639.0 R. L. This lake is fed by Banganga Nadi and by percolation from the Upper Lake; in addition a tunnel was driven through the Bund in 1899 to supplement the supply from the Upper Lake so that the water level in the Lower Lake could be maintained at the high water mark to obtain the full working pressure at the Hydraulic Turbine pumping station for driving pump.

The rainfall varies from 35 inches to 55 inches and hence the lakes are well fed every year. There is no record of shortage any year. The quality of Upper Lake water is far better than the lower lake one and hence it is used for water-supply requirements while the lower lake water serves only in supplying power for driving the hydraulic Turbine.

Pumping Arrangement:—The water supply arrangements in the city started in 1873 with a single pumping station at Yacht Club and according to the growth of population other pumping stations were added. Thus, they have now three separate pumping stations with separate reservoirs and filter plants.

These are:—

(1) Yatch Club Pump House with a reservoir and filter plant at Shamla Hill at an elevation of 179 ft. above lake level.

(2) Karbala pumping plant with a reservoir and filter plant at Ledgah Hill at an elevation of 270 feet above lake level.

(3) Pulpukhta Hydraulic pumping plant with filter plant at pump house and reservoir on Arehra Hill at an elevation of 138 feet above lake level. No. 1 and 2 are provided with electric pumps while No. 3 has a hydraulic Turbine driven by water power.

The average daily supply through all the three pumps comes to 2.5 million gallons daily for a population of about 1,20,000.

Filters:—The filtration plants have recently been installed by Messrs. Candy Filters Ltd. at a total cost of Rs. 8.70,800. They are Raid Gravity Filters and give a highly purified quality of water with a guarantee that the filtered water would be free from all suspended matter and be of normal colour. odour and taste. That there would be no trace of B. Coli in 100 c.c. sample and the total Count developed on Nutrient Agar in incubated for 24 hours would not exceed 50 per cubic centimeter.

The capacities of the plants are:—

(i) Shamla Filters..............72,000 gallons per hr. (Connected with Yacht Club pump).

(ii) Pulpukhta Filters...............42,000 galls. per hr. (Hydraulic Turbine pump).

(iii) Ledgah Filters..............42,000 galls per hr. (Connected with Karbala pump).

An interesting feature of these plants is the hopper shaped settling tanks.

Raw water from the venturi flume, to which alumina solution has been added and mixed, enters the settling tanks through individual inlet pipes is fitted with a sluice valve and terminates at a

point approximately 3 ft. above the bottom of the hopper. The velocity of discharge from the inlet pipes together with the rapid change of direction of the water as it leaves the inlet pipes and commences to rise in the hopper bottomed tanks produces ideal conditions for the building up of the floc. The water then rises up in the hopper at a gradually reducing rate and finally passes out of the tanks into a collecting channel which is formed in the concrete surrounds of the settling tanks. The floc being relatively heavy settles at the bottom of the hoppers and all of the incoming raw water has to pass through this settled sludge. This arrangement, where the incoming water to which alumina has already been added, passes through the sludge already formed in the settling tanks, ensures the most rapid and efficient building up of floc.

Distribution:—The city proper and Jehangirabad are served by the combined supplies from the Shamla reservoir and Turbine Plant. The latter pumps direct into the supply mains during the day while during the night it pumps into the Arehra reservoir which serves the Central Jail as well as the factories located at distant positions on the east. The supply in the city is continuous for 24 hours but during the night the pressure is reduced by diverting the Turbine pump to the reservoir instead of pumping directly into the Mains.

The Ledgah reservoir supplies independently to the portions on the west of the city Jehangirabad and Ahmedabad. Here the supply is intermittent and runs only during the morning and evening hours of the day. The intermittent supply in this case is possible because the reservoir is at a good height and full pressure throughout the mains is obtained within 15 to 20 minutes. In the case of the main city it was not possible as the height of reservoir was not sufficient and the network of mains of small diameter are long and complicated as they

were laid long back in 1873 when the requirements were much less. Thus it takes several hours to give sufficient pressure throughout the mains after it is once shut off.

WATER SUPPLY TO BOMBAY

Vaitarna-cum-Tansa Scheme.

"Bombay to-day needs a supply of 236 million gallons of water per day," according to a speech delivered by Mr. N. V. Modak at the Indian Institute of Architects, Bombay.

The Vaitarna-cum-Tansa Scheme is being pursued for the augmentation of the city's water supply and tenders have been called for at the moment. A new dam is to be constructed at Vaitarna near Magalpada, some 10 miles from Khardi Station on the North-East section of the G.I.P. Railway, 65 miles distant from Bombay. It will impound 46,000 million gallons of water in the lake. Vaitarna is expected to impound the required quantity even in the scantiest years thus preventing any possibility of water scarcity in the city.

The Vaitarna dam will be a massive cement concreate structure of the gravity type, 1,700 feet long including 350 feet of spillway. The top of the dam will be 253 feet above the river-bed; this allows a 10 feet free board over the full supply level.

The top of the dam will be kept 28 feet wide including two parapet walls. The foundation of the dam will rest on the hard, impervious Deccan trap of the river-bed. Various factors such as shear and tensile stresses due to heat of hydration, friction between layers of concrete and concrete foundation, probable uplift due to pervious rock bed, etc., have been duly considered in designing the dam.

As the proposed dam will be the first all-concrete dam of its kind to be constructed in India, a special testing laboratory will be set up at the site to exa-

mine the various ingredients of the concrete as well as the concrete itself at various stages. The concrete for the dam will have a maximum water-cement ratio of 0.55 and the maximum size of aggregate will be 6 inches. Setting and shrinkage cracks will be avoided by limiting the temperature of the wet concrete to 80° F. by the addition of tube ice. Besides, there will be a special cooling plant at the site to cool down the concrete by circulating water at 35° to remove the heat of hydration while curing and setting. A specially designed batching plant will control the proportioning of the cement. As far as possible the concrete will be compacted with the aid of internal type vibrators. All forms to be used for casting the concrete will be of well-seasoned air-dried timber as it has been proved that absorbent forms are harder and more durable than non-absorbent ones such as steel shutters. The concrete mixture will be loaded in bottom dump buckets and carried by loco trains and finally dumped in position by means of ropeways or by cranes moving on a specially constructed bridge along the length of the dam.

Inspection galleries which will be provided at 40 ft. intervals along the face of the dam will help to locate the internal drainage pipes running alongside for periodical cleaning. It is proposed to install four radial type automatic gates, each 70 ft. by 20 ft. deep, over the crest spillway; also two undersluices with two emergency gates in front of them.

A horseshoe shaped pressure tunnel, 10 ft. 6 in. in diameter and concrete lined with a bed slope of 1 ft. in 1 mile will convey the Vaitarna water into the Tansa Lake. A 96 in. diameter steel pipe at the Tansa end of the tunnel will supply water directly to the City under the full head of the Vaitarna Reservoir. This pipe will be laid beside the existing two 72 in. steel mains between Tansa and Powai. On its course to Tansa the tunnel line passes over

the Balvant and Tasu Nallas and the connection will be effected by a steel pipeline of similar diameter supported on masonry bridges.

Lahore Water Works:—The water famine resulting from the heat of May and June, and the tornadoes caused by the heavy showers in Lahore have brought home to them the necessity of taking in hand immediately the water-supply scheme. The Lahore Municipality, in order to get an expert's opinion before undertaking the work, sought the assistance of Mr. A. W. Stonebridge, M.I.C.E., who, after going through the details of the original scheme, observed that the entire scheme required to be recast. According to him, they would not depend upon the river for their supply, as the river was constantly changing its course, and therefore suggested that the tube wells should be sunk for this purpose, as no other reliable source of supply seemed available in Lahore. In order to get a supply of 10 million gallons per day, Mr. Stonebridge suggested that they should have 14 tube wells, which should work in rotation at least 10 working at one time. This would give an output of 750 gallons per minute. To reduce the maintenance charges, it was proposed by Mr. Stonebridge that they should have a hydro-pneumatic tank on each well, and automatic switch gear should be used so that the pump should switch on and off as required. The running cost of this scheme was estimated to be 2 annas per 1,000 gallons, including depreciation and repairs as against 2½ annas per 1,000 gallons for the river scheme. Mr. Stonebridge also laid great emphasis on providing waste detection meters, as it would result in considerable economy. This scheme was completed on the partial type, i.e., a few tube wells added every year according to the financial position.

Matheran Water Works:—Here also with a view to removing all risk of water scarcity in Matheran; the delightful hill station, and health resort, we

understand that a thorough survey of the Charlotte Lake was carried out. This lake is the main source of a water-supply. The Consulting Engineer to Govt., Govt. of Bombay, Mr. R. A. Collett, M.I.C.E., after carefully going through, suggested that something must be done to conserve the water, which is practically wasted on account of the overflow of the lake between October and January every year, instead of going into the expensive new scheme. The idea seems to be to increase the present water supply by about 1|5th of the lake's capacity, which is about 15,830,200 gallons of water.

Khed Water Supply:—Khed, a taluka town in the Ratnagiri District, is situated on the Bombay-Konkan-Goa Road, about 60 miles from Ratnagiri. There was great scarcity of water, and the town depending upon the supply from local wells which often ran dry in hot season. The Mamlatdar of Khed, who is the chairman of the Notified Area Committee, called for investigations to be made in 1925 for a piped water supply scheme, and necessary surveys were subsequently carried with the result that the present scheme was taken up in 1934. A loan was raised with the sanction of Government, and the work was carried out under the P.W.D. supervision, and estimated to cost Rs. 1,50,000 for the following works:—

(1) A pick up weir at Boraj Nala.

(2) A gravitation main of about 8 miles length of which 6″ hume pipe section of 3½ miles. and 5″ C.I. main for 4½ miles.

(3) A service reservoir.

(4) A distribution system for the town.

It was found that the Boraj Nala, having large Plateau rich in subsoil water as its catchment area, has good perennial springs capable of replenishing not less than 1 lac gallons per day even during the hottest days of the year. A suitable site having

rocky foundation was selected for the pick up weir for diverting the flow of Nala into the inlet chamber. The work was completed, and all the localities of the town supplied with pipe water.

The ideas behind giving these examples are "Examples are better than precept."

In short, the most economical procedure in a water-supply scheme, is to take and use the source of water nearest to the population to be served, provided it is adequate in quantity, and of suitable quality for domestic consumption, and thus save capital and maintenance costs in long lines of mains, way leaves, etc.

Practical Case:—Recently had occasion to consider a case, where due to smallness of mains, very inadequate pressures were experienced, some 10 miles from the service reservoir, although, during the periods of minimum draught during night hours, there was a static head in the mains of 234 ft., i.e., 100 lbs. per sq. inch. This very great head rapidly disappeared as the day's draught of water gradually increased, and from 8 A.M. to about 2 P.M., no supply of water was available from the mains at the distant point of draught. After 2 P.M., the pressure slowly returned, proportionately to the reduced consumption. The most economical and inexpensive remedy proved to be the construction of local reservoir storage accommodation for the purpose of collecting, during the night hours, when the mains were, relatively speaking, idle. The most suitable remedy for this in many such cases, by boosting of water. As per remarks of Maxwell, in his book, on "Water supply problems and developments," that the boosting of water through long lengths of small mains has its limits, owing to the high pressures attained on the delivery side of the booster and the shock on the mains, in cases where the booster pump is automatically cut into and out of duty. When double the quantity of water is forced

through the main, the waste or loss of head due to friction is increased four times, and if three times the water is pumped through, then the loss in head is nine times.

Conclusion:—A weak and inadequate supply invariably causes frequent complaints from the consumers, and is also a source of danger to life and property, in case of fires, hence boosting of water supplies then come into picture.

Weakness of pressure in the mains may arise, for example:—

(1) Overloading of mains, owing to the increasing demands for water, and additional demands due to building developments. (2) Inadequate size of mains, when first laid down. (3) Reduction in clear effective diameter, due to the internal corrosion. (4) Excessive draught of water from the mains, in the lower parts of the area of distribution.

These difficulties can be met by:—

(1) Laying larger mains suitable to the demand. (2) Scraping or cleaning of mains. (3) Erecting water towers or stand pipes, and pumping the water to the increased elevation. (4) Boosting a portion of the supply up to such an additional pressure as will give the required terminal head.

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CHAPTER II.

"DESIGN OF WATER DISTRIBUTION SYSTEM"

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Before proceeding to the design of distribution systems, it will be well to notice briefly the sources of supply and storage of water, and method of delivery to the town or district to be served. Broadly speaking the supply may be either by gravitation or pumping or from mixed sources.

The gravitation sources are more often, especially for large water works undertakings, as Bombay, derived from the catchment or drainage area of upland districts, and the water impounded in the artificial lakes or storage reservoirs, unless the water from natural lakes can be utilised.

The pumping sources may be from deep wells or bore holes or from rivers as in Calcutta, and it is also frequently necessary with such sources of supply to provide storage reservoirs as a reserve to draw upon in dry times.

Mixed sources of supply are resorted to in many instances, the pumping sources serving to supplement the gravitation supplies.

Now come to the design of the distribution systems, which was somewhat static between the years 1900 and the advent of the Hardy Cross system of analysis in 1936, but since that time the subject has been a very live one.

The two systems of supply:—(1) Constant. (2) Intermittent Supply System.

The distribution system ordinarily costs much more than any other portion of a water works system, the cost varying from say 50 to 70% of the total, and a commonly accepted figure in English and American practices, being 66% to 67% The cost of mains and valves usually amounts to 80% of the values of the distribution system, It is therefore, ob-

vious that for economic reasons alone very great care should be taken in its design or redesign.

The Water Engineer is rarely asked to design a water distribution system to serve the community where no such system existed in the past, but nowadays he is asked to design extensions or improvements to the existing system. Generally, the existing systems were not designed in the modern sense, and in few cases just grown. As the years passed, the locations of greatest demand changed, and the communities expanded, requiring extensions to be made. Also in many cases the population became concentrated, resulting in sharply increased demands on feeders and sub-feeders.

Design of Water main grid:—Water works distribution systems is designed to supply two classes of Services namely:—(1) Everyday, domestic, commercial and public use of water, in short, say, ordinary daily flow or use. (2) Water for fire extinguishment.

In the first case, the consumption is relatively uniform over the area served, and is well distributed over 24 hours of the day, but in the second case, the rate of draw is high for small time.

The first questions to be faced now are the consideration governing the quantity of water required for these two classes:—

(a) Will water be under constant pressure.

(b) Will water be required for manufacturing processes.

(c) Is the district completely sewered

(d) Have the houses water closets

(e) Are baths commonly fixed in the majority of the houses.

It is found in practice, that almost every town supply has its own particular rate per head. 30 to 45 gallons per head per day is a very ample supply for domestic and flushing purposes. The average consumption for fire purposes in American cities is at

the rate of one-tenth gallon per head per day. A basis of calculation of the consumption of water for fire extinction commonly used in America is as follows:—

$$Y=2.8\sqrt{x} \qquad C=\frac{1000}{\sqrt{x}}$$

Where Y=No. of fire stream needed, each giving 250 gallons per miniute,
C=Maximum rate of consumption for fire in gallons per head per day
x=Population in thousands.

The engineer is now in a position to estimate water requirements.

Storage facilities:—In as much as the distribution system represents such a large portion of the cost of a water works system the engineer designing it should very carefully consider the advisability of providing either underground or elevated storage or both. If distribution reservoirs are properly located, it will be found that the cost of pumping stations and filtration plants, as well as transmission and distribution mains, will be lessened materially.

As stated by the eminent American Water Engineer Mr. Freeman in his book that "In the existing systems, the provision of elevated storage will often be much more economical than the reinforcement of existing mains." The ideal size of storage tank, as funds permits, is equal to, "Outflow must be equal to inflow," "i.e. say 20,000 gallons per day."

It should be noted that the amount of water to be stored and the location and elevation of such storage and local problems, should in each case be given careful study. Standpipes, of course, should be provided only where the natural elevation of the ground will make them effective in the development of head, as it is never considered economical to use a flat bottom storage tank, where the tank itself must provide the elevation to secure the proper pressure.

If elevated storage of from 20 to 40 gallons per capita is provided, the rate of pumping can be made constant throughout 24 hours of the day. Even with

the provision of elevated reservoir of from 5 to 10 gallons per capita, the peak rate of pumpage can be reduced by half its excess over the daily average. The provision of such storage will enable the community to avoid high electric peak demand charges, to secure more uniform pressures, to protect against power outages, and give better operation of pumping equipment, to say nothing of the saving in the cost of the distribution system.

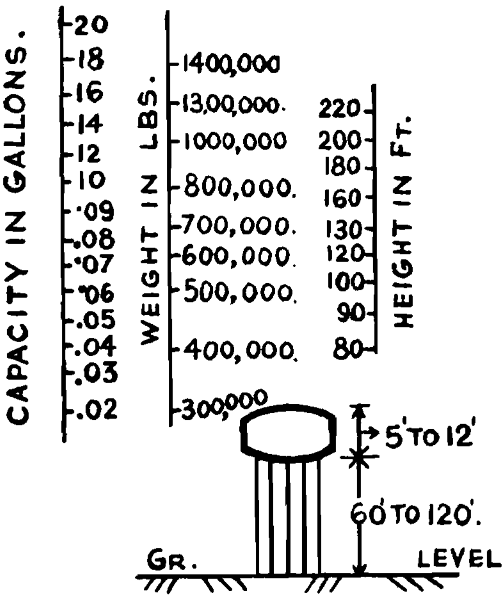


FIG. 7 :- Nomograph for approximate values of capacity, weight and height of Radical cone type elevated tanks.

Fig. 3

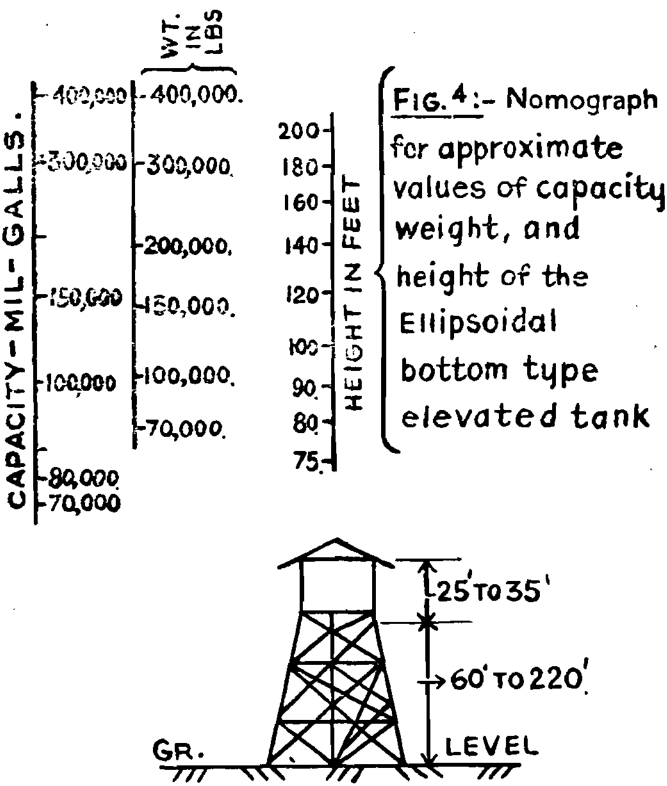


Fig. 4

Figures 3 and 4 show graphically the relationships to one another of capacity, height and estimated weight of elevated tanks. These graphs to be used only for rough estimations of weight. For accurate estimates of weight companies specializing in elevated storage should be consulted.

The fires are ordinarily of short duration, it is apparent that the cost of the distribution system

may be reduced by the provision of reservoir storage to meet the fire demand rate. The location of such reservoir storage, and its effect on the valuation of distribution system are local problems, and must be solved individually. Yes, its effect on the total valuation of the system will be greatest when topographical conditions allow the storage to be at such an elevation that it will float on the distribution system. Its value will be less, when it is located at the ground level, as the pumping station, but at the far end of the distributing pumping station. Elevated storage to provide for 10 hours fire use is very costly, and is not economical.

Distribution System:—It is advisable, in cases of towns, where there is too much difference of levels, to divide the town into the "Zones of Pressure." There, the Town, say X, has been divided into the High and Low level zone. All places in the town, in question, below 30 ft. and above sea level is supplied by gravity, from the low level service reservoir with a terminal pressure of 30 ft. of water at the furthest point in the zone. The whole town is divided into divisions of water mains (branching off from the trunk mains), district water mains, and further, branch water mains. According to the usual practice, the pipes should be designed to carry twice the quantity per head per day, to cope with the maximum demands, *i.e.*, for the absolute maximum supply which is twice the daily supply. Frequently, it is practicable to supply the increased demand, say for some reason, the pressure in a distribution system, or in part of it, is deficient, then, by laying new pipes, but occasionally the expense of this may not be justified, and in such cases, "Booster Pumps" may be installed to augment the pressure. The general tendency in all the modern Water Works is to maintain a high terminal pressure at the ends of the water mains. The minimum pressure in America and European Water Works practice is about 50-80 ft., as for example

Bombay 50 ft. and Calcutta 40 ft. The question of daily rate of water supply, varying from 30-210 gallons per head per day according to the nature of the town. In determining the diameter of the pipes, the usual theoretical formulae must first be consulted, and in laying out the pipeline, care should be taken, that at no intermediate point on it does the pipe rise above the level of the mean hydraulic gradient at that place, due to dividing the total length by the available head. All pipes are usually protected from decay and oxidisation or incrustation of iron water mains, by a process developed by Mr. W. T. Tate, the cement lining for water mains, internally and externally by a coating of coal tar, pitch and mineral oils applied hot, according to Dr. Angus Smith's Patent. This is found to be the best protection where the pipes are to be buried, and painting outside is better, where the pipes are exposed to the air and sun. Sir Alexander Binnie, in his book "Rainfall; Reservoirs and Water Supply" lays down authoritatively that no cast iron pipe having less than a minimum of 4″ diameter shall ever be used in any water distribution system. Having thus decided on the minimum size of pipes, the minimum terminal pressure, the maximum rates of domestic and fire protection supply, as per Burton for 200 cu. ft. per minute in addition to the absolute maximum domestic consumption, as a minimum fire protection provision for any large town water main of distribution system should be of sufficient capacity to take this load, and the population of the different divisions, distributes the service load for each of the different kinds of water mains is easily found out, from which by a process of trial and error, the sizes of the various mains can be fairly and accurately worked out. The formulae generally adopted in these calculations is Prof. King's Experimental Formulae for incrusted C.I. pipes as $H = K_1 \frac{V^2}{2g} \times \frac{L}{1.25}$

Determination of High and Low Level Zones of Service:—The bottom of the low level service reservoir, as now designed, is 88.0, and it is found from actual calculations of the pipe system on the basis of the Hydraulic Gradients, usually allowed in waterworks practice, that the frictional and other losses of head, during periods of maximum demand, between the service reservoir and the end of the longest main (5 miles plus 1,400 ft.) amount to 57.91 ft., say 58 ft. or nearly 11.02 ft. per mile which agrees closely with the American Water Works practice. The hydraulic gradient level at the point, where the leading low level trunk water main enters the low level zone, works out to + 72.00 from this point, the maximum distance to any point at the upper limit of the low level zone may be taken at one mile, allowing 30′ as the terminal pressure, and 12 ft. for the frictional and other losses of head, in the leading service mains thereto, we get 72—(30 + 12) = 30 ft. as the possible upper limit of the low level zones. With a view to maintaining a maximum pressure throughout, the entire low level system of 30 ft. and commanding storeyed buildings, situated at the upper limit of the low level system, it has been decided to adopt plus the 30 contours, as the upper limit of the low level zone.

Main Line and Distribution System:—At every change of direction or gradient be caused the resultant pressure is great, the pipe at that place should be weighted down by means of concrete bed. For this, the concrete can be rammed on the sides, and over the pipes to the required depth. Similarly, where two or three branches meet at one place, and there is the possibility of the pressure getting increased, the pipe or rather the portion of the pipe should be covered up in the concrete blocks

Distribution grid:—After the quantity of water and the type of storage required are decided, the Water Engineer is in a position to determine the

layout and size of the distribution grid. The grid should be designed so that not less than 50psi of pressure shall be obtained at the hydrant, in case of fire. In practice, the pressures of from 70 to 100 psi are more satisfactory for all purposes.

We think formerly, it was quite common practice to boost pressures on receipt of a fire alarm, but this practice is disappearing, largely due to the reliability of motor driven fire pumps, and the accessibility of hydrants under all weather conditions.

The three systems have been employed in the layout of the distribution network:—

(1) *The ring system*:—It is consisting of a large main around the periphery of the area to be supplied, and a gridiron of laterals extends from this outside main across the district.

(2) *The central main system or plan*:—This consists of a large main laid through the centre of the district with laterals branching from it, to form the network reaching all the parts of the districts.

(3) *The intermediate plan or system*:—This combines the best features of the ring plan, and the central main plan, and consists of an interior ring in the network not extending to its outer boundaries.

The opinions of the eminent Water Engineers, after investigating the merits etc. of the three systems reads thus:— "Either the central main plan or the intermediate plan was more economical than the ring system, and added that a layman engineer might innocently add about 1|3 of the cost of a distribution system, without gaining any advantage in efficiency.

In the distribution system, two types of pressure drop are usually encountered:— (1) Loss of head in the primary feeder, which varies in general with the local draft. (2) Loss of head within a relatively small area surrounding the fire, due to concentration of fire flow.

In practice, large mains should be provided at intervals of from ½ to ¾ mile apart in both directions, and these areas filled in with smaller pipes to form a grid. The loss of capacity of tar coated C. I. pipes as they age was fully considered by a committee of New England Water Works Association who reported in 1935, that the average actual loss in capacity of tar-coated C. I. pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52%. The sizes of smaller pipes, which form the grid are usually tentatively determined from past experience, but depend upon the number of fire streams required at any given point. The most common practice in this case, for small cities and the outer districts of large cities to have 6" cross connection or mains with 8", 10" or 12" mains at intervals of from 4 to 6 blocks apart. The recent American and English practice is not to employ mains of less than 6" or 8" in the grid system. The 4" main is usually quite satisfactory for supplying water for ordinary use, but unsatisfactory for supplying it for fire use through hydrants, as per remarks of the fire Engineer, M. R.B. Wooley, M.I.F. Eng. (Lon.), in his article on "Fire station Design, and How to extinguish the Fire." A satisfactory approach to the determination of the size and arrangement of the small mains, is the circle method described hereafter.

The circle method is very useful, where it is required to determine the sizes of the intermediate mains in a large distribution system. It requires a knowledge of the economical velocities in the pipes, and here is reproduced in most text books on Water Supply, various formulas for finding the velocities. For ordinary sizes of pipes, and for average conditions, it can be shown that the economical velocities will run from approximately 3 ft. per second for 4" pipe to 4 ft. per second for 20" pipe, where water is required to be pumped, as per

Hydraulic Tables, by Mr. P. J. Flyan, C.E., based on Kutter's formula of very great service.

The steps in this method are as under:—(1) Take the grid shown in the Figure 5, and assume the demand of the district to be concentrated at a fire at point "A", and for example take 2,500 gallons per minute as the fire demand.

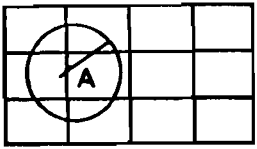


FIG. 5

Fig. 5 *Typical Portion of a Gridiron OR Reticulation.*

(2) In as much as the fire streams from hoses are unsatisfactory, when the hose length exceeds 600ft, draw a circle whose radius is about 80% of this length, (say 500 ft.) and whose centre is at A.

(3) Count the number of pipes cut by this circle, and say 6 pipes. If the circle is tangent to any pipe or cuts across any pipe, take the number of pipes cut as two, for each such instance.

(4) Find out the economical velocity (take here 3 ft. per second).

(5) Find the diameter of a single pipe that will carry the total demand at the economical velocity *i.e.*, we have taken 2,500 gallons per minute at 3 ft. per second with a coefficient C=100 (Downing), the size of pipe will be found to be 18 inches.

(6) From table (1-A) on page 62, find how many 4″ pipes are equivalent in cross sectional area to one 18″ pipe, *i.e.*, 20 of 4″ pipes=1 of 18″ pipe.

In this example, 6 pipes were cut by the circle, therefore find from the table 6 pipes whose combined area=20 of 4" pipes. The nearest solution is 4 of 8" pipes, plus 2 of 6" pipes, which are equal to 20 of 4" pipes.

TABLE (1-A)

EQUIVALENT PIPE SIZE.

	SIZE OF PIPES IN INCHES.													
	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"	30"	36"	42"	48"
Number of 4" C. I, pipe having same capacity.	1	2.9	6.2	11	18	28	39	54	70	113	208	330	497	706
Number of 4" C. I. pipe having same cross Sectional area.	1	2.25	4	6.3	9	12.2	16	20	25	36	48	81	110	144

TABLE (1-B)

The number of branches of a given size that will be supplied by delivery pipe may be obtained from the below table.

Diameter of delivery pipe in Inches.	Diameter of branch pipe in inches. No. of branch pipes.								
	4″	3½″	3″	2″	1½″	1¼″	1″	¾″	½″
4″ ..	1	1	2	6	12	18	32	66	181
3½″ ..	..	1	1	4	8	13	23	47	139
3″ ..	..	..	1	3	6	9	16	32	88
2″ ..	..	..	..	1	2	3	6	12	32
1½″ ..	..	..	..	..	1	2	3	6	16
1¼″ ..	..	..	..	..	..	1	2	4	10
1″ ..	..	..	..	..	..	..	2	2	6
¾″ ..	..	..	..	..	..	..	..	1	3
½″ ..	..	..	..	..	..	..	..	..	1

Head of water in feet and Approximate Discharge in Gallons per Minute for Lines of piping ½" Bore to 6" Bore allowing for an average number of Bends & fittings.

TABLE 1C:—This gives Approximate Discharge, under a head of from 1 Foot to 500 Feet for a pipe Line 1000 Feet in length.

Note.—For other lengths Factor from Table 1D below should be used.

Head or Fall in Feet	DISCHARGE IN GALLONS PER MINUTE												Head or Fall in Feet
	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	3½"	4"	5"	6"	
1	.16	.45	.93	1.63	2.57	5.28	9.22	14.5	21.3	29.8	52.1	82.2	1
2	.23	.64	1.32	2.30	3.63	7.46	13.0	20.5	30.1	42.1	73.6	116.	2
4	.33	.91	1.87	3.26	5.14	10.6	18.4	29.1	42.7	59.6	104.	164.	4
6	.40	1.11	2.29	6.29	12.9	22.5	35.5	52.2	73.0	127.0			6
9	.49	1.36	2.80	4.88	7.71	15.9	27.7	43.6	64.1	89.5	156.0	246.0	9
12	.57	1.57	3.25	5.64	8.90	18.3	32.0	50.4	74.0	103.0	180.0	285.0	12
16	.66	1.81	3.73	6.51	10.3	21.1	36.9	58.1	85.4	119.0	208.0	328.0	16
20	.74	2.03	4.18	7.28	11.5	23.6	51.2	64.9	95.4	133.0	233.0	367.0	20
25	.82	2.27	4.67	8.14	12.9	26.4	46.1	72.6	106.0	149.0	260.0	411.0	25
30	.90	2.48	5.11	8.92	14.1	28.8	50.5	79.5	116.0	163.0	285.0	450.0	30
40	1.04	2.88	5.31	10.3	16.3	33.5	58.3	92.0	135.0	188.0	329.0	520.0	40
50	1.16	3.21	6.61	11.5	18.9	37.4	65.2	102.0	150.0	210.0	368.0	581.0	50
75	1.42	3.93	8.10	14.1	22.3	45.7	79.9	125.0	184.0	258.0	451.0	712.0	75
100	1.65	4.55	9.35	[illegible]	25.7	52.8	92.2	145.0	213.0	298.0	521.0	822.0	100
150	2.03	5.59	11.5	19.9	31.5	64.9	113.0	178.0	262.0	366.0	637.0	1011.0	150
200	2.33	6.42	13.2	23.0	36.3	74.6	130.0	205.0	301.0	421.0	736.0	1161.0	200
250	2.61	7.20	14.8	25.7	40.7	83.7	146.0	230-0	337.0	471.0	824.0	1303.0	250
500	3.69	10.20	20.9	36.4	57.5	118.0	206.0	325.0	476.0	667.0	1164.0	1840.0	500

Table 1 C.

TABLE 1D :—When the pipe line is more than or ess than 1000 feet in length. The figure taken from Table No. 1 C must be Multiplied by the corresponding Factor chosen from the following.

TABLE 1 D.

Length in Feet	50	100	150	200	300	400	500	750	1000	1250	1500
Factor	4.47	3.16	2.58	2.237	1.837	1.58	1.414	1.154	1.0	.895	.817
Length in Feet	1750	2000	25003	3000	4000	5000	7500	10.000	5 Miles	10 Miles	50 Miles
Factor	.756	.707	.63	.577	.577	.447	.316	.195	.138	.138	.0618

Example;—Approximate Discharge of line of piping 4″ bore 5000 feet long under 30 feet head.
Approximate Discharge for 1000 feet line from.

TABLE 1 C—16·3 Gallons per Minute Factor TABLE 1D—4·47

∴ Apprx. Discharge $= 16{\cdot}3 \times 4{\cdot}47 = 72{\cdot}9$ gallons. *Answer.*

TABLE (1-E)

POPULATION	DISCHARGE AT 8 Galls per head per hour.	MAX. VELOCITY In ft/sec.			
		5"	6"	9"	12"
500	0.177	1.31	—	—	
600	0.213	1.63	—	—	
700	0.249	1 91	—	—	
800	0.285	2.19	—	—	
900	0.32	2.46	—	—	
1000	0.355	2.72	1.87	—	
1100	0.39	3.00	2.05	—	
1200	0.426	3.28	2.24	—	
1300	0.454	3.49	2.38	—	
1400	0.493	3.79	2.59	—	
1500	0.533	4.1	2.8		
1600	0.57	—	3.0	1.29	
1700	0.603	—	3.17	1.37	
1800	0.640	—	3.37	1.45	
1900	0.675	—	3.56	1.53	
2000	0.710	—	3.74	1.61	
2100	0.745	—	3.92	1.69	
2200	0.78	—	4.1	1.77	
2300	0.818	—	4.3	1.86	
2400	0.855	—	4.55	1.94	
2500	0.89	—	4.68	2.02	
2600	0.925	—	4.87	2.1	
2700	0.96	—	5.05	2.18	
2800	0.945	—	5.25	2.26	
2900	1.03	—	5.43	2.34	
3000	1.065	—	5.60	2.42	
3100	1.1	—	5.8	2.5	
3200	1.14	—	6.00	2.6	
3300	1.17	—	6.16	2.66	
3400	1.21	—	6.35	2.75	
3500	1.24	—	6.52	2.82	
3600	1.28	—	6.72	2.90	
3700	1.31	—	—	2.97	
3800	1.35	—	—	3.06	
3900	1.39	—	—	3.16	
4000	1.42	—	—	3.22	

CUSECS	Gallons Per Hour	CUSECS	Gallons Per Hour
0.10	2250	0.39	8775
0.11	2475	0.40	9000
0.12	2700	0.41	
0.13	2925	0.42	
0.14	3150	0.43	
0.15	3375	0.44	
0.16	3600	0.45	
0.17	3825	0.46	
0.18	4050	0.47	
0.19	4275	0.48	
0.20	4500	0.40	
0.21	4725	0.50	
0.22	4950		
0.23	5175		
0.24	5400		
2.25	5625		
0.26	5850		
0.27	6075		
0.28	6300		
0.29	6525		
0.30	6750		
0.31	6975		
0.32	7200		
0.33	7425		
0.34	7650		
0.35	7875		
0.36	8100		
0.37	8325		
0.38	8550		

Size	AREA Sq. ft.	Max. Permissible Velocity	Max. Discharge Cusecs	Gallons Per Hour
3"	0.05	2.36	.1180	2650
4"	0.08	2.5	.200	4500
5"	0.13	2.6	.338	7,600
6"	0.19	2.7	.513	11,500
9"	0.44	3.2	1.408	20,435
12"	0.78	3.5	2.73	61,400
15"	1.2	4.00	4.80	
18"	1.76			
24"	3.14	5.5	17.27	

$$\text{Pressure drop} = \frac{L \times v^2}{1600\text{-}D}$$

In Canada and U.S.A. the flow formula which has found the widest application for water works use, is the one devised by Hazen and Williams, namely.

$$\text{Vel}=\text{C}\ \text{R}^{0.68}\ \text{S}^{0.54}\ 0.001^{-.004}$$

The system recently used for determining the amount and direction of flow through the mains and the head losses upto any point in the grid is devised by Professor Hardy Cross in 1930. Here in this system, the pressure contour map is prepared, and the contours compared with those of a theoretically perfect system. This contour plan will show at once the weakness of the network, and larger mains can be substituted, where required or decreased in size when necessary, and the network reanalysed on this basis of the changed pipe sizes. This method further helps the Water Engineer to see whether the necessary water can be fed by the mains, so that the pressure losses at the hydrants in case of fires, are not excessive.

The preceding description of the determination of the size and layout of the distribution system has reference to a new system, but the same principles apply to the redesign of an existing system, and differ only in the application.

Physical nature of the system:—Before the size of pipe in the distribution system can be determined the Water Engineer has to decide on the type of mains that will best suit the community in which they are installed, and whether a cast iron pipe, steel pipe, R. C. C. pipe, Asbestos cement pipe, and their being subjected to corrosion, etc.

Cast iron pipes have established their soundness as they have been in use and have instances of giving services for nearly 225 years as in Wieberg and C.I. pipes in Bombay have served for nearly 75 years. The life of hume pipes is still an unknown factor. It is worthwhile for the water works engineer to

make comparative study from the economic point of view, as their responsibility is very great in our free country now.

A very suitable position for the distributing mains is about 3 ft. away from the edge of the footpath and 2′-6″ to 3 ft. deep, and the other pipes and cables etc. should be 3 ft. away from the water main, as prescribed by Act of Parliament. The distributing pipes to be circulation from two directions, and the mains connected both ways, doubles their capacity, which is a very great advantage at times of heavy draughts. The hydraulic gradient or slope (means a straight line drawn from the point where the head of water enters pipes to the termination of the pipe line or point of discharge) governs the discharge of the pipe lines and if the pipe lines laid down without due regard to the hydraulic gradient, led to very disappointing results and needless expense. For example, say 6" pipe laid within the hydraulic gradient of 1 in 100 would discharge 0.48 cubic ft. per second, and suppose, the hydraulic gradient of 1 in 100 were broken, and the pipe rose, and forms the hydraulic gradient of 1 in 400 would only give, a discharge of one half is 0.24 cubic feet per second, as per Hydraulic law:—The discharge varies as the square root of the head, and 6" pipe would be larger than necessary for that portion to discharge the 0.24 cubic feet per second, on the steeper gradient.

Example:—Calculation to show, whether 3" main proposed to be laid is sufficient or not for supplying a big estate, as follows.

Data:—Six buildings consisting of ground and three upper floors, having 6 flats of 4 rooms in each buildings, and there are 36 flats, in all, and taking 10 persons living in each flat, the total population works out to 360 souls.

Quantity of water required $= 300 \times 50 = 18000$ galls per day.

$$\therefore \text{ Qusec} = \frac{18{,}000}{8\times 3{,}600\times 6.25.} = 0.1 \text{ cusec.}$$

With a 3″ main, area = 0.088 sq. ft.

$$\therefore \text{ Velocity} = \frac{0.1}{0.088} = 1.13 \text{ ft. per second.}$$

This is within the permissible velocity, which is 2.36 ft. per second.

Now, to find the head lost due to friction.

$$h_f = \frac{4\,flv^2}{2gd}$$

$$= \frac{4\times 0.01\times 250\times (1.13)^2}{2\times 32.3\times 1/3.}$$

$= 0.6$ ft., hence it will be seen that the head lost is negligible.

Example:—In absence of a pressure chart, it is not possible to ascertain the actual draw off. However the following calculation gives the draw off through 3″ main at say 18 lbs. per square inch pressure, which is the minimum obtainable in the main.

Solution:—Assume length of main is 320 ft. and dia = 3″.

Equivalent length, including friction in valves, bends, etc., = 400 ft.

Available pressure = 18 lbs. per sq. inch
Height of storage = 20 ft.

$\therefore$ Pressure drop = 41′—20′ = 21 ft.

$$V = c\sqrt{rs}$$

$$= 80\sqrt{1/6\times 21/400}$$

$= 4.5$ ft. per second.

$Q = AV = 11/4\times 1/16\times 4.5 = 0.219$ cusecs.

The drawing capacity of 3″ main connection will be 118,000 galls./day. Answer.

Example:—Quantity required is 25,000 gallons per day. Find the size of main.

Solution :—$\frac{25,000}{3600} \times \frac{1}{6.25} = 1{\cdot}1$ cusec (for 8 hours supply.)

Assume, average pressure=22 lbs. per sq. in.

Height of storage tank = 22 ft.

∴ Available head = $22 \times 2.3 - 22$ frictional losses
$= 50.6 - 22 = 28.6 - 4.6$ (say)
$= 24$ ft.

Let, length of pipe = 1,100 ft.

Supply received through 4″ main:—$Q = AV$

$Q = 0.272$ *cusecs.* $\quad = 0.08 \times 80\sqrt{4/48 \times 24/1100}.$

∴ The connection should be capable of discharging $1.1 - 0.272 = 0.828$ cusecs.

Then, try with 5″ connection,

$$Q = 0.13 \times 80\sqrt{5/48 \times 24/1100}$$
$$= 0.50 \text{ cusecs.}$$

Try further with 6″ main,

$$Q = 0.19 \times 80\sqrt{6/48 \times 24/1100}$$
$$= 0.80 \text{ cusecs}$$

∴ 6″ main connection is necessary. Answer.

Example:—Finding the gradient of main. The pressure is 20 lbs. per sq inch. and length of pipe is 340 ft., and height of tank is 12 ft.

Solution:—Pressure $= 20 \times 2.3 = 46' - 12'$
$= 34$ ft .head.

$$\text{Gradient} = \frac{\text{Head}}{\text{length}} = \frac{34}{340} = \frac{1}{10} \text{ Answer.}$$

Valves:—In the operation of a water works system, one of the most important pieces of equipment in the distribution is "Sluice Valve," and have two-fold objects. (1) For the purpose of inspection by

waste water meter; (2) To enable any particular section to be turned off for repairs, etc.

Permissible leakage from mains:—According to Flinn; Weston and Begerts' Water works hand book (Page 426), the permissible leakage from the mains:— 60 to 250 gallons per mile per inch diameter of pipe.

(2) Leweth proposes 60 to 80 gallons per inch per mile per day.

(3) Gregory (Improvements to Columbus Water Supply) says 507 to 528 gallons per 24 hours per inch per mile.

(4) Babbitt and Donald in Water Supply Engineering, says 250 gallons per mile per inch diameter per day (Page 436). But in U.S.A. the leakages varies from 80 to 13,100 gallons per day per mile per inch diameter as per Flinn.

It is intended for European practice given by Mr. Fanning, M.I.C.E., that "the actual house service connections, which may be taken off a small distribution main is largely a matter of experience and judgment but as a rule, it may be taken that a 4" main will supply about 180 of ½"; 60 of ¾" and 30 of 1" connections.

Hydraulic investigation of existing distribution system:—Here apply the same principles for redesigning of the existing system, and let us take one by one systematically as under:—

(1) Required capacity and pressure of distribution system.

(3) Field studies of distribution system.

(3) Pressure surveys, and also by hydrant flow tests.

(4) Office studies of distribution system.

Now, dealing with this seriatim:—(1) "Capacity:— If there were no fire hazard, the hydraulic capacity of the distribution system would have to equal the maximum demand for domestic, industrials and other general uses. But for absolute safety, the fire demand would be added to this figure. *Let us take now pressure*:- For normal draughts, the pressure at the street line must be at least 20 lbs per sq. inch, i.e., 46 ft. of water, in order to raise water three storeys and overcome frictional resistance of the house distribution system, but 40 lbs. per square inch is a more desirable pressure Business blocks are supplied better at 60 to 75 lbs. per sq. in. But the main objections to the pressure as high as this, are increased leakage and wastage of water, approximately in proportion to the square root of the pressure, as per hydraulic law.

Item No. (2):—Hydraulic performance of existing distribution system is determined most easily by pressure Survey, and hydrant flow tests. There is no limit to the extent of such tests.

Item No. (3):—These yield the most rudimentary information about the network. If they are conducted both at night (maximum flow) and during the day (normal demand), they will indicate the hydraulic efficiency of the system in meeting common requirements. This is enough to know the probable behaviour of system under conditions of stress, such as are produced by a serious conflagration.

The hydrant flow tests:—The observation of pressures at a centrally situated hydrant during the conduct of test, and measurement of flow from a group of neighbouring hydrants by means of hydrant Pitot tubes, that record the velocity heads in the jets issuing from the hydrants.

Item No. 4:—The matter how energetically the study of the distribution systems is pursued in the field, hydraulic investigations of extensions, rein-

forcements, and new net works can be brought to satisfactory conclusions only in the office.

There are 3 methods of analysis which will be useful:—(*a*) The method of sections. (*b*) Prof. Hardy Cross method. (*c*) Method of equivalent pipes, which may be applied alone or in conjunction with Prof. Hardy Cross method.

(*a*) *The method of sections*:—Was used by Allan, Hazen, as a quick check of distribution systems. The circle method is given above in short. For details reading, refer to any good water supply text books.

(*b*) *Prof. Hardy Cross method*:—In which systematic corrections are applied to an initial set of assumed flows until the net work is balanced hydraulically. The basic equation given for flow correction is:—

$$q = \frac{\text{sum H}}{1.85 \text{ sum } \frac{\text{H}}{\text{Q}}}$$

when Q=flow assumed for any pipe in net work. q=flow by which Q is corrected in order to reach a closer hydraulic balance of network. H=loss of head through one pipe in network for a flow of Q, as found by William and Allan Hazen formula (already given) and 1.85 is a constant.

Discharge from fire hydrants:—This is a very important problem in waterworks distribution system, to be taken into consideration for fire fighting purposes.

Assuming the hydrant is fully opened, and is giving a steady discharge, the pressure in the main will be used up in the following ways:—

1. Loss of head entrance to 3″ pipe (Fig. 6).
2. Loss of head in 3" pipe.
3. Loss of head caused by the bend of the duck foot.

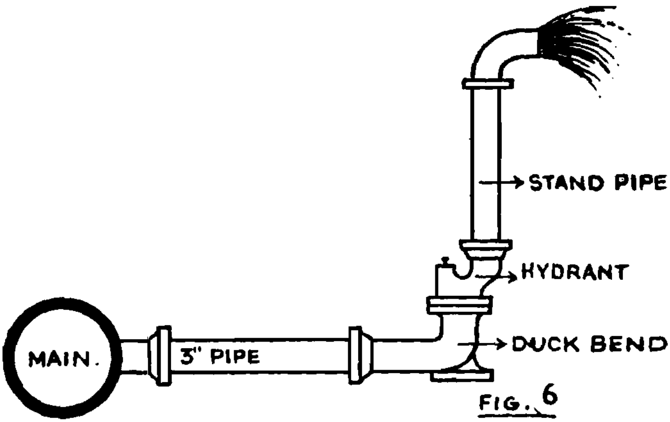


FIG. 6

4. Loss of head in the hydrant.
5. Loss of head in the standpipe.
6. Velocity head of the water at discharge.

Those losses have been calculated, and are given in table No. 2. For calculation purposes length of 3" pipe was taken as 10 ft, and loss of head worked out by Kutler's formula. The loss of head in a screwed down hydrant will vary greatly with the various patterns in use. The values in column 4 of table No. (2) are based on actual experiments carried out, on dry average type of hydrant, by Mr. H. Canmell, M.I.C.E., etc.

Screw down hydrant connected as in Fig. 9 page 82. In this case, the head in the main is used up, as in 1, 4, 5 and 6 in the first case.

(1) At the entrance of the pipe. (2) Friction in 3" pipe. (3) Loss of head in 3" Sluice valve. (4) Loss of head in bend. (5) Loss of head in standpipe. (6) Velocity head of discharge.

Now working pressure in the main at the entrance to a hydrant branch+Velocity head=loss of head in connection+velocity head at exit+pressure on

TABLE (2)

Flow in Gallons per minute	LOSS OF HEAD IN FEET DUE TO								
	Entrance to 3" pipe. 1	Friction in 3" pipe. 2	Duckfoot bend 3	Screw down hydrant 4	Stand pipe 5		Velocity head at discharge 6	Total 1 to 6, Loss of head in ft. Fig. 6,	Total 1, 4 & 5, loss of head in ft. Fig, 6
					Pipe	Elbow			
100 ..	0,2	1.5	0,2	4	0.2	0.7	1	7.8'	6,1'
200 ..	0,9	6.2	0.8	16	0.9	2.8	4	31.6'	24.6'
300 ..	2.0	13.3	1.8	36	2.0	6.8	9	70.2'	55.8'
409 ..	4.0	25.0	3.0	64	3.0	11.0	15	125'	97.
500 ..	6.0	39.0	5.0	100	5.0	19.0	24	198'	154.
1000 ..	22.0	167.0	20.0	400	22.0	69.0	96	796'	..

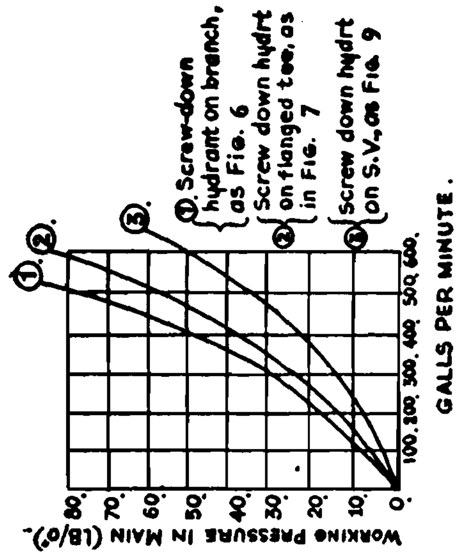


FIG. 8 (CURVE).

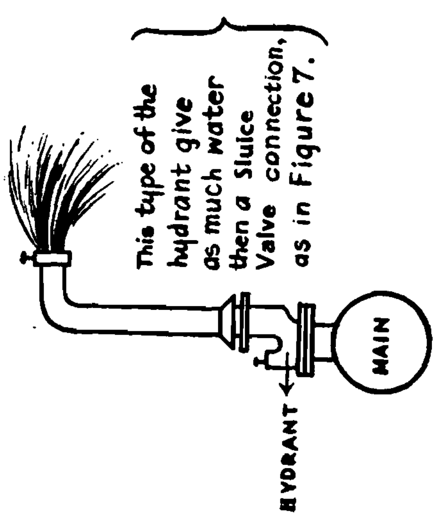


Fig. 7

water at exit, which in the case of a standpipe discharging into free air is atmospheric pressure Velocity head in the main in all practical cases is small enough to be ignored. Thus, if a hydrant were discharging and working pressure in the main were known, it would be possible to get the amount of the discharge by means of the appropriate curve in Fig. 8. The results obtained in table 2 and 3 have been converted to lbs. per sq. inch, and plotted in Fig. 8. (graph). All the calculations are based, taking the inside surfaces of the pipes and fittings as clean.

If more hydrants than one are opened, the discharge from each hydrant will be much the same as for a single hydrant until the discharge becomes large enough to reduce seriously the working pressure in the main, once this happens, opening further hydrant will decrease the discharge from those already open, and the actual increase in the total discharge will be too small to justify the extra equipment needed to collect it.

For a 3" main similarly connected, the discharge from one hydrant is 139 gallons per minute, and for 2 hydrants between 145 and 150 gallons per minute. It is not advantageous to use more than 3 hydrants on 6" main, 2 hydrants on 4" main, and more than one hydrant on 3" main. If the working pressure is more than 50 lb. per sq. inch. it might be advantageous to open 4th hydrant on 6" main, but upto 100 lbs. per sq. inch., it would not be worth while to open further hydrants on 4" main, and of 3" main. In case of 2½" hydrant only, a small increase in discharge will be obtained by sucking. In the majority of the cases, these hydrants are connected to small mains, and the danger of reducing the pressure in the main below the atmospheric pressure is considerable sucking from 2½" hydrant is, therefore, highly undesirable from a waterworks point of view, and unprofitable from the fire fighting one.

TABLE (3)

Flow in gallons per hour.	LOSS OF HEAD IN FEET DUE TO						TABLE 1 to 6	
	At entrance of 3″ pipe 1	Friction of 3″ pipe. 2	Valve. 3	Bend 4	Stand pipe 5	Velocity head at discharge. 6	Loss of head in sluice valve hydrant connections	
100 ..	0.2	1.5	0.3	0.2	0.9	1	4.1'	1.8 lbs/sq. in
200 ..	0.9	6.2	1.2	0,8	3.7	4	16,8'	7.8 ,,
300 ..	2.0	13.3	2.6	1.8	8.8	9	37.5'	16.2 ,,
400 ..	4.0	25.0	4.0	3.0	14.0	15	65'	28 ,,
500 ..	6.0	39.	7.0	5.0	24.0	24	105'	45 ,,
600 ..	8.0	57.	11.0	7.0	36.0	35	154	67 ,,

TABLE (4)

Size of main.	Length of main.	Total Discharge in Gallons per Minute, Through Hydrant One	Two	Three	Four	Five	Six
8" ..	2.000 yds.	260	410	480	520	..	..
8" ..	1,000 "	180	470	600	670	710	..
8" ..	400 "	..	..	710	850	950	1020
9"	2,000 "	..	..	580	650	690	..
9" ..	1,000 "	..	..	680	800	880	950
9" ..	400 "	..	..	770	960	1110	1240

This table (4) was obtained, taking 115ft. or 50 lbs. per sq. inch. head available which is a fair average for most systems. From Fig. 6 (graph) it is easy to get the total discharge, which will be given by any number of hydrants fed by a given length of main e.g. to find the discharge from 3 hydrants at the end of 1000 yards of 8" main the solution is to plot the loss of head in 1000 yards of 8" main for varying flows, and add to this curve the loss of head for varying flows, and add to this curve the loss of head in a hydrant discharging 1|3 of flow in 8" main. The curve thus got will give the total discharge, which will be obtained with any particular available head.

From the above table, it would be seen, therefore that the optimum number of hydrants to use on 8" main is 3 or 4 and on 9" main 4 or 5. These figures of course, include hydrants on small mains, which are near to the junction of small mains, and large mains under consideration.

In case of main of over 9" the number of hydrants available will not normally be sufficient to exhaust the delivery capacity of the main. In small mains, the discharge will be affected by the length of small main, between hydrant and the trunk main.

The main cause of the actual discharge being less than the maximum is due to the incrustation of pipes and fittings, as per remarks of Mr. H. Cannell, M.I.C.E., in his paper appeared in "Water and Water Engineering" Vol. 46 of 1943.

The subject is admirably dealt within Mr. Thomas Box's treatise on Hydraulics, and quote Mr. Box's works:-"Calculation must be made of the loss of head by friction in such pipes, so as to get the actual head on the Jet." The accumulation supply to be made available in case of big fires. This system consists of an automatic electrically driven supply designed and erected by Messrs. Taylor, Sons & Santo Crimp, Civil Engineers of Westminster, to afford

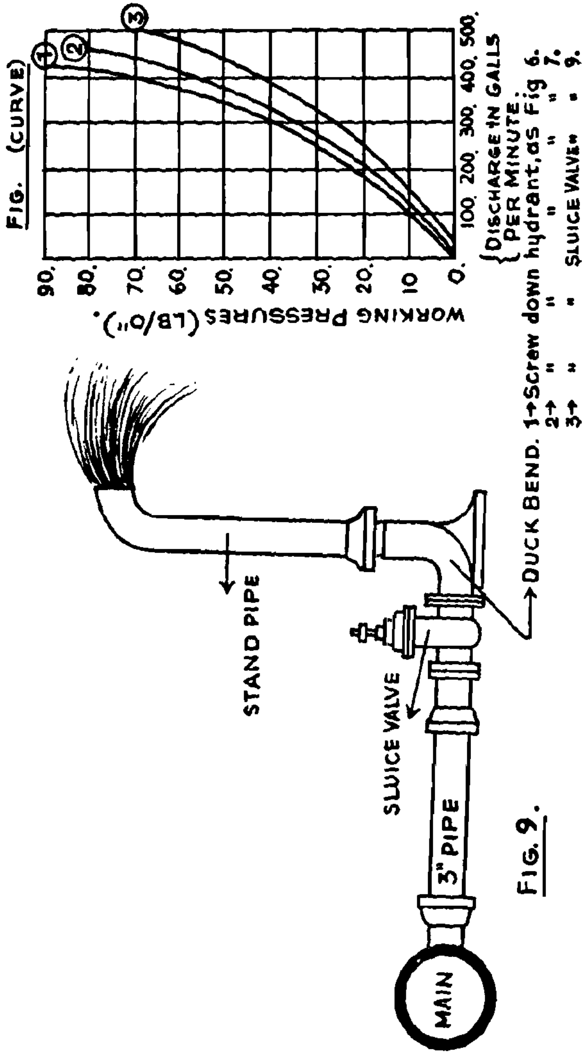


FIG. (CURVE)
90. 80. 70. 60. 50. 40. 30. 20. 10 0.
WORKING PRESSURES (LB/□").
100. 200. 300. 400. 500.
DISCHARGE IN GALLS PER MINUTE.
DUCK BEND. 1→Screw down hydrant, as Fig 6.
2→ " " " " 7.
3→ " " SLUICE VALVE " 9.
STAND PIPE
SLUICE VALVE
3" PIPE
MAIN

FIG. 9.

a supply for the higher portion of the town, where elevations are too great to be adequately served by the existing reservoir or water tower. The installation is usually placed in the base of the water tower from whence the pumps derive their supply, advantage being taken of the head of water so obtained. Electric motors were adopted with 3 throw pumps, the pumps delivering through a combined relief and check safety valve into an accumulator and main. In ordinary working only one set of pumps come into operation. As the pumps deliver more water than the district requires, the ram rises. When near the top of its stroke a lever is engaged which switches off the current. The ram then descends, and when within 4 ft. of the bottom of its stroke, the other lever is engaged which again switches on the current and starts the pump. Should an usual demand arise so that the ram still descends, a second set of levers become engaged which starts a second motor pump. This system has proved very satisfactory, and being entirely automatic in action, it dispenses with the necessity of an attendant regularly in charge.

Increasing pressure in distribution system:—It happens, not infrequently, that for some reason, the pressure in a distribution system, or in part of it, is deficient. This is due to the increase in population and insufficient capacity in pipes laid many years before; incrustation and finally the demand for a supply at a higher level than originally anticipated in the scheme. Then, the question arises of laying new pipes or enlargements of the existing mains, but occasionally the expense of this may not be justified, and in such cases booster pumps, (*i.e.*, high lift centrifugal pumps) are installed to augment the pressure. Refer to the best paper on "Pressure Boosting Station for the water works of the city of Monte Vides" by Mr. Arthur Honeysett, M. I. C. E. Proceedings of Inst. of Civil Engineers, Vol. 221, Page 123. The fixing of booster

pump on big water connections of industrial concerns, the following are essential:— (1) Booster pump is of approved type and is fixed on a by-pass arrangement on 3″ pipe; (2) a proper type of non-return valve is fixed on 3″ pipe; (3) a Safety valve to operate above the high pressure required should be fixed.

The working out of a distribution system is one of the most troublesome problems of water works, as well as one of which most books are nearly silent, and that in general is barely referred to in papers describing the carrying out of water works. Many engineers think it a part of the works of quite minor importance. The Authors would insist that it is of importance minor to no other part of the works, and the important functions of the modern Water Works and the extinction of fire—a first rate of importance and the extinction of fire is one of the principal purposes of Water Works, and this fact seems to be fully appreciated only in America and England and to a lesser degree in India.

Pitometer Survey:—Pitometer is inferential type of current meter used for measuring the flow of water in pipes and open channels. It is designed on the principle of "Pito tube". Pitometer consists of two parts, the "rod meter" and the "mano meter." The makers usually issue instruction books for the use of such a meter, giving table of coefficients of the instrument with various velocities, and they are indispensable in using such a meter. This meter is a ready means of gauging the flow in a pipe without going to the complexities of fixing a positive or inferential meter. All that is required is that a hole (1" diameter) is to be drilled and tapped at any point in a main, a plug cock is fixed, and instrument is inserted through the plug cock, the quantity of water passing can be at once determined, if a traverse of the pipe has already been taken. It is obvious that by inserting this instrument at

successive points of pipe line, the difference in flow can be determined, which may be the consumption between those points or leakage. If the flow is measured between 1 a.m. to 4 a.m. when the majority of the consumers have retired, and actually the quantity being drawn for domestic use is infinitesignal, it will represent approximately the leakage in the mains and service pipes.

Pipe Laying:—The trench is usually excavated with vertical sides to such a depth as will give a minimum cover of 3 ft. of earth over the main when laid, and of such a width as to allow 6" to 9" clearance between the pipes and the sides of the trenches. There are three forms of apparatus by which water is ordinarily drawn from the service mains, thus laid, for use, namely hydrants; house connections, and street fountains. It means that the distribution system should be planned to be capable of supplying water at a rate equal to at least three times that of the average daily supply of water the whole year.

Sterilization of new water mains:—An important possible source of pollution of a water supply, arises in connection with the laying of new mains, especially with those of large sizes. Risks may arise in various ways, when laying a new main, as under:—

(1) Pipes may have been in stock for a long time, and may have been afforded a shelter for animals, such as cats, dogs, rats, etc.

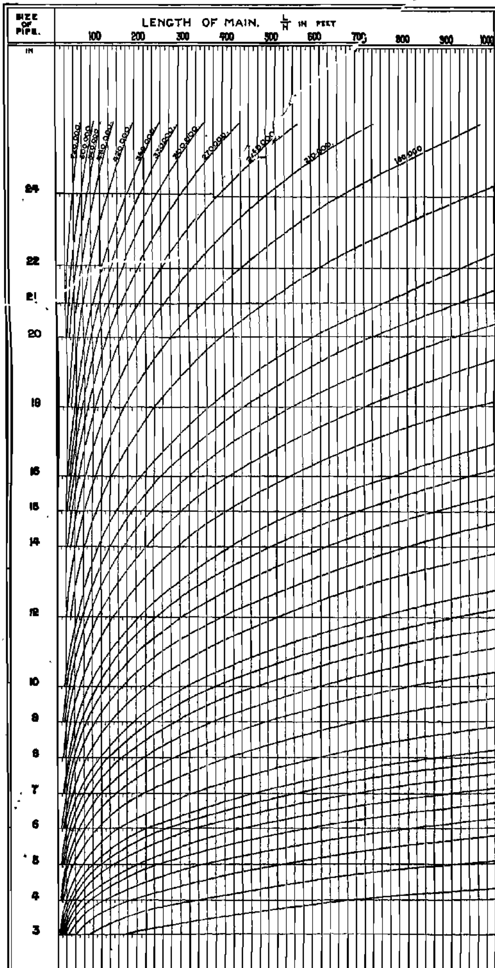
(2) Leakages from the drains and sewers may lead to contamination of the interior surfaces of the water mains.

The remedy for this is to fill new mains with heavily chlorinated water, and to leave water in the mains for several days (*i.e.* 7 to 15 days). The chlorinated water is flushed out, and the new mains refilled and flushed with water, to be used for supply, The practice of sterilization of new mains appears

to be extending considerably both in England and America, and it is of course safest to act as if pollution had actually occurred, when chlorinating the new mains the house hold stop taps should be shut off and the householders notified. The flushing through with fresh water should be continued, until no excess residual chlorine is detected in the water by tests M/s. Wallace and Teerman supply a portable chlorinating equipment for main sterilization and emergency uses of a capacity upto 40 lbs. of chlorine per day. The iodization of a public water supply for the prevention of goitre may be roughly compared with the chlorination of water for the prevention of typhoid and other intestinal disorders

———:o:———

QUANTITY CURVES & SIZE OF PIPES — FOR LONG WATER MAINS.



GALLONS PER HOUR. (Thousands.)	LBS PER MIN. (Thousands.)	VELOCITY FEET PER SECOND. IN PIPES 12"	14"	15"	16"	18"	20"	21"	22"	24"
720	120									10·2
600	100								10·1	8·5
540	90							10·0	9·1	7·6
480	80						9·8	8·8	8·1	6·8
420	70					10·6	8·5	7·7	7·0	6·0
360	60					9·0	7·3	6·7	6·0	5·1
330	55				10·5	8·3	6·8	6·1	5·6	4·7
300	50				9·5	7·8	6·1	5·6	5·1	4·3
270	45			9·8	8·6	6·9	5·5	5·0	4·6	3·8
240	40		10·0	8·7	7·6	6·0	4·9	4·4	4·1	3·4
210	35		8·7	7·6	6·7	5·3	4·3	3·9	3·6	3·0
180	30	10·4	7·5	6·6	5·8	4·5	3·6	3·3	3·0	2·6
150	25	8·5	6·3	5·4	4·8	3·8	3·1	2·8	2·5	2·1
120	20	6·8	5·0	4·3	3·8	3·0	2·4	2·2	2·0	1·8
		9"	10"	12"	14"	15"	16"	18"	20"	21"
108	18	10·8	8·8	6·2	4·5	3·9	3·4	2·7	2·2	2·0
96	16	9·7	7·8	5·4	4·0	3·5	3·1	2·4	2·0	1·8
84	14	8·5	6·9	4·8	3·5	3·1	2·7	2·1	1·7	1·6
72	12	7·3	5·9	4·1	3·0	2·6	2·3	1·8	1·5	1·3
		6"	7"	8"	9"	10"	12"	14"	15"	16"
60	10		10·0	7·6	6·1	4·9	3·4	2·6	2·2	1·9
54	9		9·0	6·9	5·5	4·4	3·1	2·3	1·9	1·7
48	8	10·9	8·0	6·1	4·9	3·9	2·7	2·0	1·7	1·5
42	7	9·5	7·0	5·4	4·2	3·4	2·4	1·8	1·5	
36	6	8·1	6·0	4·6	3·6	2·8	2·1	1·5		
		3"	4"	5"	6"	7"	8"	9"	10"	12"
30	5			9·8	8·8	5·0	3·8	3·0	2·4	1·7
27	4·5			8·9	6·1	4·5	3·4	2·7	2·2	1·5
24	4·0			7·8	5·4	4·0	3·0	2·4	1·9	1·4
21	3·5		10·7	6·8	4·7	3·5	2·7	2·1	1·8	
18	3		9·2	5·8	4·0	3·0	2·3	1·8	1·5	
15	2·5		7·6	4·9	3·4	2·5	1·9	1·5	1·2	
12	2	10·8	6·1	3·9	2·7	2·0	1·5	1·2		
10	1·666	9·0	5·1	3·2	2·2	1·6	1·2			
9	1·500	8·1	4·6	2·9	2·0	1·5	1·1			
8	1·333	7·2	4·0	2·6	1·8	1·3				
7	1·166	6·3	3·5	2·2	1·6	1·1				
6	1·000	5·4	3·0	1·9	1·3					
5	·833	4·5	2·5	1·6	1·1					
4	·666	3·6	2·0	1·2						
3	·500	2·7	1·5	·9						
2	·333	1·8	1·0							

EXAMPLES IN THE USE OF QUANTITY CURVES

These curves provide a ready means of ascertaining the size and length of Main to give a required quantity per hour when the Head is known, or vice versa, in a Gravitation Water System. It is necessary to obtain the Hydraulic Gradient $\frac{L}{H}$, thus giving the Length of Main for 1 ft. Head. Tracing this length vertically from the top line to the Quantity Curve, and horizontally from this point to the left, gives the size of pipe required.

L = Length. H = Head. D = Diameter. Q = Quantity.

Example 1.

When 2 Levels are known = Head in feet; say 110 ft.

Distance between 2 Levels is known = Length in feet of Main; say 14,300 ft.

Quantity of Water required is known = Galls. per hour; say 15,000 galls.

$$\therefore \frac{L}{H} = \frac{14,300}{110} = 130 \text{ ft.}$$

To find the size of Main: Tracing from the 130 point on top line to the 15,000 gall. curve, we find this point opposite 6·4 in. on the left-hand column for size of pipe; say 7 in. diameter.

Example 2.

Knowing Head, Length and Size of Pipe—To find Quantity.

Say H = 200 ft. L = 42,000 ft.

D = 12 in.

$$\text{Then } \frac{L}{H} = \frac{42,000}{200} = 210$$

Tracing a line from 12 in. bore horizontally to meet a line traced vertically from 210 on top line, we find they meet between the 54,000 and 60,000 Quantity Curves.

The desired quantity is about 55,000 gallons per hour.

Example 3.

Knowing Head, Size of Main and Quantity—To find Length of Main.

Reading from Bore to the Quantity Curve will give a point under the top line showing Length for 1 ft. Head.

Multiplying this quantity by Head available will give the total Length of Main.

Say H = 210 ft. D = 10 in. dia.

Q = 30,000 gallons per hour.

We find opposite 10 in. diameter on 30,000 gall. curve, a point under 290 ft. on top line.

290 × 210 = 60,900 ft.

Example 4.

Knowing Length and Size of Main, what Head would be required for a certain Quantity? Proceed as in last example, dividing the Length given on top line into the total Length of Main, giving head thus:—

Length of 9 in. Main = 3,300 ft.

Quantity = 42,000 gallons.

$$\frac{3,300}{90} = 37 \text{ ft., say.}$$

CHAPTER III.

"CLEANING OR SCRAPING OF WATER MAINS"

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"CLEANING OR SCRAPING OF WATER MAINS"

As far as the authors know, this subject is one which has not received much attention in India. Scraping is an operation that is very frequently performed in England and America.

It is well known that all Water Mains (generally Cast Iron) before being laid, have been generally coated with what is known as:—"Dr. Angus Smith's composition". *"The object of coating Cast Iron Mains is to prevent oxidation."* The metals used in the manufacture of the mains or pipes are unable to withstand corrosive action of water or air. *By arresting corrosion, the life of cast iron pipes are prolonged for a more or less considerable time.* For this purpose, different substances are applied to the surfaces of the pipes or their surfaces are treated in some special ways. It is, therefore, necessary to apply a protective coating of another substance, which is either too expensive to use entirely in the manufacture of pipes or which is utterly useless under the circumstances, except as a coating material. The cast iron pipes are coated, and the coatings are as under: (1) Ordinary lead oxide or iron oxide. (2) Hot Coal tar. (3) Galvanising. (4) Bituminous Composition, such as Dr. Augus Smith's Composition. (5) Glass enamelling. (6) Coat of black or Magnetic oxide of Iron, and this process is known as Barffing.

Uses:—(1) *Lead oxide or iron oxide* are used for protecting Waste pipes, Soil pipes, Ventilating pipes; and Rain water pipes. For these pipes, frequently renewal of paints are necessary as the rust preventer.

(2) *Hot coal tar* is occasionally used for the interior and exterior of gas mains, and stronger kinds of Soil pipes, and this coating is not suitable for

water supply purposes, as the water passes through it, is generally tainted by the tar oil, present in coal tar.

(3) *Galvanising* is used for rain water pipes, soil pipes, ventilating pipes, and waste water pipes and this coating is fairly suitable for this purposes, but acid atmosphere acts on zinc and the coating is readily destroyed. It is rarely used for galvanizing cast iron water mains or pipes.

(4) *Dr. Angus Smith's Composition* acts in some considerable measure as a preventative against the internal corrosion of the Water Mains. The composition referred to, consists of coal tar and pitch, which have been boiled until all the crude naphtha, and other volatile oils are got rid of and 5 per cent of linseed oil is added. The effect of this oil is to make it elastic; after the pipes are cast they are freed of sand, and heated to from 400°F. to 500°F., and are immersed for 20 minutes in the composition which is raised to the same temperature, before the pipes are dipped into it. The pipes are lifted out, and allowed to drain. When the pipes are used for Drainage, and Water Supply Work, the second coating applied with Dr. Angus Smith's Composition. It is generally restricted to cast iron water mains and drain pipes.

Dr. Angus Smith's Solution in its original form was probably a sound protective coating for pipes, but in these days, it is rather a myth. Coating of pipes by dipping can be a snare, and a delusion and when the process is little more than a gesture its specification can be a definite danger, giving a sense of false security and becoming a factor in setting up localised, and, therefore, accelerated corrosion, if detected or damaged intermittently.

(5) *Glass enamelling* is used, when acidic water is to be carried. The interior surfaces of cast iron soil pipes, ventilating and drain pipes are preserved by a thin coat of glass enamel. The pipes, after

casting operations, are coated inside with a mixture consisting of lead oxide, Silica, tin oxide, china clay, and borax, and placed in special kilns, and the temperature raised so as to fuse the glazing solution, which adheres firmly to the cast iron surfaces in the form of a glass.

(6) *Bower Barff Process i. e. Barffing* consists of heating the articles to be treated to redness, by subjecting them to the action of superheated steam. The steam is decomposed, and a film of magnetic oxide of iron is formed on the surfaces, and this for a time prevents further oxidation taking place. This process of coating is suitable for boilers, and Hot Water Supply pipes.

Are the Water Engineers planning for water mains reconditioning in the Post-war programme ? The question asked to the authors on this most important subject of Water Supply Engineering, and the answer was in the negative, so far as the Indian Post-war programmes are concerned; the post-war construction is certain to include both conditioning and the re-conditioning of Water mains.

There are two practical methods of scraping or descaling the water main in America and United Kingdom as follows:—

(1) *Mechanical Process, i. e.*, by the use of the pipe scraping machines, described hereafter.

(2) *Chemical Process*:—This chemical method of recent date, has many advantages, *i.e.*, encrusted water mains, leading to the lack of volume and pressure, frequent excavations and consequent high cost of maintenance, do not fit in with efficiency that will be demanded of responsible authorities.

This chemical system of descaling, *i. e.*, "clensol system of chemical descaling," deals with this problem through chemical means or by scraping and brushing by power winch, according to the type of deposit found. The chemical descaling of upto 800

yards of pipe is possible with one excavation only. In either method, the water mains are restored to full bore.

The first pressure scraper that was made to pass through the pipes by the pressure of the water itself, was invented by the Engineer, Mr. J. G. Appold, in 1873, and the paper was read by Mr. John Little, Engineer of the Torquay Water Works, giving a description of the Appold Machine in his paper, Description of the Mechanical Scraper for removing incrustation in the Mains of Torquay Water Works, before the Institution of Mechanical Engineers, in 1873. This pressure scraper machine was further improved by Mr. Thomas Kennedy of Kilmarnock, and nearly the whole of water main scraping work was carried out with this improved machine. This machine consists of two distinct portions connected by a swivel joint, the front portion carrying the steel scrapers, and the rear of wrought iron or steel propelling pistons. The latter are somewhat smaller in diameter than the bore of the pipe to be scraped, on ground that the pistons may not cut the corrosion, and water must be allowed to pass them. Leather discs, intersected by radial cuts, and stiffened at the back by lead plates placed behind each piston. The springs, with steel cutting edges, are arranged in two sets of four each, the set behind breaking joint with that in front so as to effectively scrap the whole internal circumference of the main.

The most interesting paper was read on the subject as, "Internal Corrosion of Cast Iron Pipes," by Mr. Mathew Buchan Jamieson, A.M.I.C.E., (Proceedings of Inst. of Civil Engineers, London, Vol. XIV of 1881), and to quote from his description:— "It is usually found by experience, personal and otherwise, that the greater the purity of the Water Supply, the more severe in its corrosive action, on account of the Oxygen and Carbonic acid, contained

in the water, which, in the absence of mineral matter as in hard waters, is left more free to act upon the interior walls of the pipes. The amount of corrosion is also found to be proportional to the volume of water passing through the pipe. For example, at a dead end, the corrosion is almost nil, whilst in the constantly flowing main, the instances have been known of 6″ main once being so much obstructed by corrosion that the clear way did not exceed 2" diameter.

To remove internal deposits or corrosive scale, etc., from the mains, the "hatchboxes" or "doorpipes" are provided, and the scraping machine is inserted, when the pipes require cleaning. The hatchbox or doorpipe is an open topped pipe with a doorway long enough to admit the scraping machine into the main.

Scraping Process:—The scraping procedure is that all the water connections, etc., are first located, and the main is shut off, and the tapping ferrules are removed and replaced with the short ironplugs. It is important that all services ferrules be found, before the scraping of the main is proceeded with, otherwise any ferrule end projecting inwards may damage the cutters of the scraper. In cases of difficulty in finding service pipes, an "electrical main finder" such as the "Sharman," (Price & Belsham Ltd.) may be very advantageously used. In addition, all the hydrants to be removed, and the tees plugged off with special flanged plugs.

At one end of the length of main to be reconditioned, a piece is cut out, in absence of a hatchbox or doorpipe in case of old Water Work, and any internal deposits or corrosive scale from the pipe is removed by means of say a petrol driven rotary "Adamson" scraper, and the main is then well flushed through. All the other end of the length of main under treatment, a piece is cut out, and all side branches opened up, and plugged with say

wooden stoppers. Sluice valves are also removed and replaced by straight pipe temporarily jointed for the purpose of scraping with Gibault joints.

The length of main to be scraped in a day depends upon the size of the main, and the amount of corrosive deposit to be removed, but may be usually more or less from 150 to 180 yards. Scraping process cannot be done around the bends. These bends must be removed and replaced by bends lined by means of a special lining machines. During the reconditioning work, an alternative means of supply to consumers must be provided.

Proving the clear diameter:—Having thus isolated the main, a cable is then drawn through with the aid of drain rods or a cord attached to a wood and rubber piston forced through the main by water pressure, and a prover with oversized rubber washers or plungers is passed through the pipe. This method is used, where the head is insufficient to drive the scraper, say under 15 ft. head. The prover indicates the largest diameter of the lining scraping machine, which can be used, and also discovers the position of any obstructions in the main. The squeezee action of the plungers removes silt and moisture from the interior surfaces of the main. The prover which is slightly less in diameter than the pipe under treatment, consists of a hardened steel cylinder centrally held in the pipe by flat steel springs.

It appears rather strange and mysterious to an onlooker to see six or eight sensible looking workmen lying prone with their faces to the Mother Earth, and for each in turn to suddenly jump up and off at a run beyond the farthest man, while the Inspector in charge of the scraping operation follows at a quick walk with the sounding rod (Stethoscope) in hand, stopping now and then and anxiously applying his ear to find whether the scraper has struck or not, and the only sign of the scraper's pre-

sence being the sound of the water rushing past. When a solid obstruction is met with, the scraping machines can be heard coning against it with a dull thud, then the signal is given for the turncock to turn off the water, and turn it on again *suddenly*. This is repeated, if ineffective, but sometimes all persuation is lost upon the recalcitrant "beastee." The pipe track is opened, and the pipe is struck a few smart blows with a sledge hammer. Scraper then may move off or may not. If not then a wisp of hay is inserted at the hatchbox, and when it reaches the scraper, it forms a species of packing, and the extra pressure thus generated seldom fails to send the scraping machine off, but at times all expedients fail, and nothing remains but to cut the pipe open to remove the cause of the obstruction. Generally, it is found out to be a large piece of lead, carelessly run into the pipe when being laid. The scraper will pass round curves quite well, if not too sharp, i.e., if not less in radius than about 14 times the diameter of the pipe. By using one set of springs and one piston, the scraper being constructed to suit, bends of about half the radius as foresaid can be scraped. Pipes as small in diameter as 5" have been scraped by the pressure scraper, but only when the head of water available to drive the scraper was very considerable, say not less than 50 or 60 ft. As a rule, this size is scraped by hand. The friction on the sides of small pipes is so great in proportion to the area, and the space so small to accommodate the scraper, that it is impracticable to scrap them with the pressure scraper. For example, a pipe is 5″ diameter, and the circumference is say 15″ and on which the blades act, while the area is only 19½ square inches. *i.e.*, to say the area is only about 1¼ times the circumference. For a pipe, say 20" diameter, the circumference is 63", while the area is 314 square inches, or about 5 times the circumferences. It is, therefore, clear that 20" scraper can be driven by about 1|5 the pressure necessary

to drive a 5" one. As a matter of fact, a much less proportion is sufficient to do the work. The scraping is done during the day, but where the main passes through a town, operations are carried out early in the morning, before much traffic is on the road.

Hydraulic scraping is far cheaper, and is practicable in all pipes, exceeding 4″ in diameter; curves and bends of any ordinary radius (3 ft. in a 6" main) do not effect the process, and will remove the stones, lead and other abnormal obstructions. When the main has been designed for hydraulic scraping, and is properly provided with the hatch-boxes, the cost of scraping is very small in comparison with increased discharge obtained, after scraping it. It is the usual practice among the English Engineers to scrape pipes whenever the discharge falls off sufficiently to seriously interfere with the supply.

Water mains supplying Torquay (Devonshire) a birth place of the pipe scraper, are a typical example.

A 9" and 10" main was laid in the year 1859, and was first scraped in 1866, and thereafter, it was found necessary to renew the process yearly. One year, without scraping is sufficient to reduce the discharging capacity. Mr. P. A. Morley Parker in his book on "Control of Water," states that Bombay 24" main, which even after scraping only gave 0.81 of its discharge which news is interesting, as indicating the possibilities of incrustation in the tropical climates.

The following is the table at Page No. 97 to show the increase in discharging capacity of the mains secured by the Scraping Process.

Advantages of the Process:—Considerable improvement in the Water Supply was experienced as a result of the reconditioning work done at, say, Manchester, particularly in the case of mains with

Serial No.	Place.	Dia. of Pipe.	Discharge in galls/minutes.		Percentage of increase.
			Before scraping.	After scraping.	
1 ..	Aberdeen ..	4″	620	747	107
2 ..	Bombay ..	24″	317	464	19
3 ..	Boston ..	48″	423	659	30
4 ..	Torquay ..	9″ & 10″	499	531	28

"dead ends," where corrosive deposits are usually the greatest. Hydroflo gauge tests, showed an increase in the water supply of from 50 per cent to over 400 per cent. The average cost per yard for all sizes of pipes was about 40 per cent of the cost of renewing the mains, including all charges and final reinstatement.

Corrosion and incrustation of iron water mains often produce a serious decrease in the discharge, owing to the increase in roughness of the surface of the pipe, and the reduction in its cross-sectional area. In some cases (as per the remarks of Sir Alexander Binnie) the discharge has actually been decreased by 50 per cent. in a few years, and scrapers have had to be introduced. To overcome corrosion, iron pipes may be lined with cement mortar by the Centrifugal process. This method, while producing a very dense film of mortar, is confined to lining straight pipes in the factory, and before they are laid in the ground. Bends and specials must be lined by hand, and pipes already in service can be treated only by being taken up lined, and relaid, the cost of which is very prohibitive.

Bends and Specials:—A process (applicable *in situ*) developed by Mr. Tate is equally applicable to lining bends, etc., whether in the factory or in service. The process requires cement mortar of a relatively high water cement ratio. The mortar is mixed constantly for considerably longer than is the usual practice, and has a slump of approximately 11 in.; in this consistency it is poured into an opening in the pipe line, from whence it flows readily and without segregation any desired distance along the pipe.

Apparatus:—It consists of a spreader, whose maximum cross section is the same in size and shape, as the bore of the pipe when lined. The spreader is a tapered tube, having a conical nose

tapering to a trailing skirt, which has a number of fine perforations. During the passage through the pipe, the spreader is proceeded by several spreader guides shackled together by means of universal joints. These guides are fitted with rearward set arms of spring steel, which fit the bore of the unlined pipe, and their function is to ensure that the spreader is maintained in the true axial alignment in the pipe.

Dehydrator holes:—When the spreader is pulled through the pipe, the mortar is forced on the wall of the pipe with increasing pressure, and the excess water escapes through the small dehydrator holes provided in the skirt of the spreader. Sufficient quantity of water is removed in this manner to reduce the mortar to such a consistency that it became self supporting and adheres finally to the pipe.

Bends are also lined in a similar manner, except that the spreader is almost Ball shape, so as to maintain an even thickness of mortar irrespective of the radius of the bend. It is interesting to note that the water service may be restored within fifteen hours of lining.

Arsenic in Cast Iron:—According to the report of Professor Eugen Piwowarsky, of Aachen, the corrosion resistance of cast iron can be very appreciably increased by the addition of 0.1 to 0.3 per cent. of arsenic. If the arsenic used is antimony free, the mechanical properties of cast iron are also improved, whilst its density is increased.

The cement lining to the water mains *in situ*, has during recent years been introduced by Mr. W. Taren Tate, of Sydney, Australia, and the process is called "Tate pipe lining process," and is done by Messrs. Tate Pipe Lining Process Ltd., Victoria Street, S. W. 1. The process of cement lining is given in brief:—After the main has been scraped, flushed and proved as to size and freedom from obstructions, the length of the main under treatment

is then filled with the cement mortar or with Ferrocrete or cement Fondu mortar, by passing it through a long necked funnel, and forcing it into the water main proposed to be lined with the cement, by means of rubber pluggers.

Cement mortar must be of a suitable consistency for passing into and through the main, and is made of two parts washed sand to one of cement. After fully loading the main with the mortar, the funnel is replaced with a blank flange, and the lining machine is drawn through the soft mortar, by means of the cable. In this way, a thin lining of cement mortar is passed into the interior surfaces of the main under a pressure of approximately 130 lbs. per square inch. The curing of cement mortar under water results in a hard, dense and smooth lining.

The relative importance of internal and external corrosion depends on the circumstances, in the case of each pipe line, but on balance, failure due to external attack are more to be feared. The following are the salient points, as under:—

(1) The inhibition of corrosion of metal incorporated in waterworks pipe lines should be one of the foremost concerns of the waterworks Industry.

(2) It is extremely difficult to assess the degree of danger to any particular pipe line from corrosive elements in water and soil.

(3) Adequate protection gives a general and effective answer to the problem of corrosion.

(4) Protection to be effective, must be continuous. Corrosion is accelerated when protective coatings partly fail or are subject to localised defect or damage.

(5) The electrical testing of protective coatings would detect, "pinholing" and local failures, and is the practice in America.

As incrustation in cast iron pipes is so great that it reduces the discharge by 30 to 40 per cent, the following remedies are suggested particularly while re-using old pipes scraped and cleaned to increase their life:—

(1) Lining pipes with cement.

(2) Providing bitumen lining.

(3) Chemical methods of cleaning the pipes by using chemicals patented for this work

(4) Using purified and chlorinated water only for flow in pipes.

(5) Keeping constant flow of water in the pipes to prevent alternate wet and dry of the surface.

Thus with an initial life of 40 to 50 years, and by increasing the usefulness by scraping, and by making the bore smooth by any of the remedies suggested above, the pipes are good enough for a total life of say 100 years.

A lot of experimental work was done at Bangalore for the Bangalore Water Supply. The incrustations were removed from the old pipes and when treated they were found to be good for a further use, and a great saving was effected.

A reliable and good quality cast iron pipes satisfying all the required test of British Standard Specifications are now being manufactured in the Bhadravati Iron Works in Mysore. These have been tried in some places, at Maharashtra and Karnatak, and found them to be very good and reliable.

An example of a case of providing a concrete lined pipe main at Secunderabad, is given as under:—

The 6″ old existing corroded cast iron water main supplemented by a subsidiary main from Malkaj Giri Tank, which is situated about half a mile from Lallaguda, carries water supply to the Nizam State Railway Workshop, Offices and Staff

quarters, at Secunderabad. Due to the incrustation and the insufficiency of the present water supply, a new pumping system capable of discharging about, say 1,530 gallons of water per minute against 150 ft. head was erected at Hussein Sugar. This new type of main has been selected by the N. S. Rly. authorities, and of 16" diameter. This pipe line of 16" diameter runs along the Nizam State Railway embankment for a length of about 8,350 ft. up to Elephant Bridge, near Secunderabad Station, to discharge water into a masonry reservoir at Lallaguda, which was sufficiently large for the storage of their further requirements.

The 14" diameter hume pipe lines was also laid in the year 1933 for the water supply from Hussein Sugar Tank to Lallaguda, when Mr. Wilkinson, the present Chief Engineer, was the then Ag. District Engineer, Headquarters, Nizam State Railway, and it was told in December 1946 are behaving most satisfactorily. These new pipes were tested by Col. Graham Smith of Poona Engineering College, and a similar test, a few months back in February 1935, was also carried out by Mr. G. U. Rao, B.Sc. (Lon.), A.M.I.C.E., Sanitary Engineer to Government of Madras at Chidambaram. The thickness of the hume steel plate is $\frac{1}{8}$ inch.

In conclusion the process of the cleaning and the scraping of the water mains is very very important, and should be carried out regularly at the intervals of 3 to 5 years by the Water Works Authorities, or whenever the discharge fall off sufficiently to seriously interfere with the water supply.

For the purpose of the design of the large pipe lines in the future (the paper was read by Alfred Atkinson Barnes, A.M.I.C.E., before the Institution of Civil Engineers, London (Paper No:-4241) Volume CC VIII, in February 1919, on "Discharge of Large Cast Iron Pipe Lines in relation to their Ages") Mr. Barnes recommends that an allowance

in the diameter for about 10 years of incrustation is permissible, which represents a diminution of about 31% below clean discharge. This is equivalent to designing the pipe line so as to carry when new 45% more than the desired final discharge, and to prevent the quantity from falling below the required discharge.

There is another interesting paper read on "Note on the Condition of Steel Water mains, after 25 years' service," by Mr. Arthur Edmund Breton Hill, M.I.C.E., (Paper No:-4258 the proceedings of Institution of Civil Engineers, London, Volume CCV, January 1920) and worth also a glance.

It is needless to say that Hume Pipes are the best suited for water supply, being free from rust and tuberculation. The flow of water in hume pipes is far made better due to smooth internal surface, as compared to the flow of water in the unlined metal pipes. *Experience in India, too, has proved beyond* doubt that hume pipes are not also affected by sewage gas from inside or outside, even after a long use of 10 to 15 years. The main advantages of such pipes to be used in the Drainage Schemes, are due to the strength lime bedding not being required in the trenches, and secondly they can easily withstand the heavy load of deep trenches. The infiltration galleries with the use of hume pipes are giving good results in Madras Presidency, during the last good many years.

One more example of it is as under:—In Bellary it was decided by the Engineers of the Municipality to have the extra supply of 3,000 gallons, which will be pumped into their 12" main from the water works at Hagari. The Municipal Council consulted Engineers of M|s Volkarts; Richardson & Cruddas; South Indian Export Co. and others. The expert and most economical advice was eventually from Mr. F. A. Adhard of South Indian Export Co., the firm once supplied the mains to the

Municipality in 1927, who, as Dy. Sanitary Engineer had investigated Hagari Water Scheme, gave the following opinion:—"It was thought inadvisable to attempt to supply 19 lakhs of gallons per day through the existing 12" main (its present discharge being only 5 lakhs without house service connections) but pointed 12" main is clean, *i.e.* full bore is available, the opinion was advanced that it should be safe to pump approximately 8 lakhs of gallons per day or 550 gallons per minute through the existing 12" main. In order to make certain that 12" main can carry its full capacity, the main should be examined at various points. The hatch boxes were provided, and the main was scraped as per advice under pressure without difficulty, and thereby saved considerably.

The Authors, wish to point out that this interesting subject, and statements made etc., are not the results of arm-chair musings, but are based on the detailed personal investigation and enquiries.

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CHAPTER IV.

"DETECTION & PREVENTION OF WATER WASTE IN PUBLIC WATER SUPPLIES"

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"DETECTION & PREVENTION OF WATER WASTE IN PUBLIC WATER SUPPLIES"

Waste of water, in a public water supply is the quantity of water drawn, and not consumed for the legitimate and useful purpose of the consumers. There are very few cities in the world, where the water is not wasted in one way or another. Waste of water develops co-incidently with development of Water Supplies. The waste is due to failure of the consumers to appreciate the value of water, and they think that water can be used without regard to economy. Waste may either be intentional, careless or through ignorance. It is to the Engineers, who for financial reasons are not in a position to prepare a Scheme, which would serve as a permanent solution to their problem, and who have to make the best of their available supplies, and when the juggling of sluice valves, and all other methods of increasing the supply have failed, the question of detecting waste of water comes to mind. Waste prevention and detection are the product of the Nineteenth Century. indeed of the Victorian Era.

The detection and prevention of water waste by the default or neglect of the consumers is a matter of great importance to the Municipal Engineer, and to Water Supply Authorities, and in fact, it is very often one of the most ardous and unpleasant tasks, which Water Officials have to perform. The ever-increasing demand for the precious liquid, and the corresponding increase (usually) of the difficulty and expense of obtaining it, have led to drastic methods being resorted to, to cut down its misuse. In a certain town in Ireland, all the water used is obtained and paid for, from a separate Water Board

and at a high rate too, under an agreement that when the statutory allowance has passed through the meters, in any 24 hours, the officials of the Water Board in question, have the right (and oft-times use it, too) of shutting of the supply, and leaving the district absolutely dry. Now bearing in mind that the town has a large summer population, such an action in the height of summer results in nothing short of a water-famine. Hence, it was decided to install at a fairly stiff outlay, waste water meters of the differential type, which were introduced first in about 1880 by Mr. G. F. Deacon, a Borough Water Works Engineer to the Liverpool Corporation, over 50 years back. This meter is chiefly used for measuring Waste Water flows in the water mains. These meters were then placed in various positions in the district, together with the requisite valves, by-passes, etc., hence, in fact the administration of Water Works consists largely in a struggle against this insidious evil. Public waste of water occurs through the leaky mains and fittings, such as Hydrants, standposts, latrines and urinals and baths, but the total of all these is small compared with the private waste, not only through the taps, which require rewashering. Prevention of waste of water, when once detected, is a simple matter, and merely involves the repairs of the leaks, the replacement of defective fittings, or the rewashering of taps. It should be remembered that any saving made will be a saving every day. The public water taps, which are meant to benefit the people, are many times carelessly left open, and gallons and gallons of water wasted, before any one has the good sense to turn off the tap. It reduces the pressure in the mains, and renders the whole distribution system inefficient. In all towns, a certain amount of waste will occur in spite of every precaution.

Causes of Waste:—(1) The prevailing impression among the major portion of the householders is that

the water they get through the taps has got no value. (2) Most of them again have got a mistaken idea that waste means cleanliness. (3) While others commit waste from indifference and carelessness, and if it be borne in mind, that the wilful waste of water supplied by Water Works is simply stealing. The authors when in charge of the Distribution Branch of the Water Works, have come across more than hundreds of cases of the wilful waste of water, of which one example will suffice. On early morning inspection of the property occupied on the block systems, found with great surprise that two taps of ½" in size, one in the nahani, while the other one in the kitchen were left open, and the water was allowed to run to waste. On questioning the double graduate tenant (B.A., LL.B.) said: "If these taps be closed, then he would not be in a position to have the bumper supply of water", and added that the supply of water will be turned off, say between 10-30 a.m. (B.T.) and 4-0 p.m. (B.T.), i.e., pressure curtailed to avoid shortage, and wastage of water. The other example is as follows:—The Bombay Water Supply is copious— 76 gallons per day for every man, woman and child, but in many localities, it is sadly mal-distributed, and in others, there is a criminal waste by the users. We know of a tenant in Girgaum, who went on a Holiday to Kathiawar, closed his flat from without, but left open the water tap within for three months' ceaseless waste of water. The true fact is this, that the increased waste of water has led the Officials of the Bombay Municipality to lower the pressure of supply, between 10-30 a.m. and 4 p.m., because it is estimated that nearly half the quantity of water supplied is wasted, and that, but for this evil, the supply of water would have been uniform throughout. The whole of the Bombay Island is divided up into 7 Wards, i.e., from "A" to "G" Wards, of which "F" and "G" Wards get their Water Supply direct from the trunk main lines while the rest of the wards in the

city are supplied from the Service Reservoirs one at Malabar Hill and the other at Mazagaon (known as Bhandarwada Reservoirs). These two reservoirs are filled up during the night, but by 10-30 a.m. (B.T.), the water had been almost used up, and consequently the Municipal Authorities had to throttle the supply between 10-30 a.m. (B.T.) and 4 p.m. (B. T.), so as to allow these reservoirs to be filled up, and the citizens are supplied with water under normal pressure. The remedy for the low pressure lay, however, was with the public; if they did not waste water, they would get it at a higher pressure for 24 hours. The rapid growth of buildings in several parts of the City, i.e. the more the number of the buildings, the greater is the wastage of water. The total amount of water connections in Hyderabad Deccan, in the year 1942 amounted to 50,000, with the yearly increase of nearly 1,000 connections.

These had to some extent been the cause for the increased wastage. Small leakages are generally the worst, because they are not easily detected. For example, a large burst in the water main is seen at once and made good. The authors from their experience of this work find that one of the most usual sources of waste in Bombay are water closet cisterns and the storage tanks. When the housewife is of cleanly habits, and imbued with a liking for the Sanitary Reforms, the water supply is heavily drawn upon. As a rule, the local authorities are inclined to shut their eyes to this evil. The only really effectual mode, by which waste of water can be reduced to a minimum, is by the proper supervision of water apparatus put up by the consumers. The discovery of waste of water is a matter of great difficulty, and the duty is one of the most unpleasant and thankless task. When the waste arises from the defective fittings, the only course is to inspect the premises where such defect is suspected, but a large number of houses will often be visited, before the waste of water is dis-

covered. Hence, the great difficulty and expense attending Waste Detection and Prevention.

In small towns, the cost of waste detection meters would form an insuperable obstacle to their use and some simple (*i.e.*, only sounding) or portable appliance, i.e., one portable Deacon Meter is sufficient for the use of the Water officials in their search for waste, if the funds are available.

1. *Water Waste*:—This is nearly always very considerable, sometimes enormous, but decidedly decreased in many districts of late years. Variously estimated to range from 30 to 70% of the total supply; to equal total amount used to be (rarely) several times the amount properly used (America). Probable that in a great number of districts about half the supply is wasted, which is the extent of proved waste at Boston, U.S.A. Of this waste, the major part occurs on consumers' premises, the remainder in mains, etc.

2. A certain small percentage (about 10%) in mains chiefly is deemed by some authorities to be unavoidable. The remainder should be preventable by careful measures, as high class fittings, water waste detecting and preventing appliances, rigorous inspection, and in particular, by metering. Comprehensive metering is a cardinal remedy.

3. The common prevailing waste is a calamity, and millions of Rupees worth of water annually being needlessly squandered in Indian Water Works alone.

Through a hole of ⅛″ in diameter in a pipe, 2,280 gallons of water will escape in twenty-four hours, at a head of 100 ft.

The Continuous System:—In this system of water supply, water is let out in the pipes all 24 hours, and is available to the householders any time he opens the tap. The one great defect of this system is that the waste of water is very great. In the intermittent System, water is let out only in

the pipes at fixed hours of the day. At the outset, it would appear that this Intermittent System is a more rational system, because water is available to the public when they need it, and waste during the remaining period is prevented; even if the taps are left open, there is no water to run to waste. The storage of water is the greatest evil of the Intermittent System, both as regards to pollution and waste. Water stored in the house in the pots, etc., is also wasted to a very large extent, because the housewives are generally in the habit of throwing away all the water so stored every day, in washing, cleaning the pots used for storage, and again storing water for use. This is good from the point of view of health, because the stale water is thrown away. But the wastage is enormous. Many householders waste more water in this way only than its use. In Europe *i.e.*, the West, the Intermittent System is abandoned. But this system is very useful, where the water supply is scanty, and the head available is poor.

The above-mentioned three mistaken notions, therefore, should be rooted out from the minds of the people. It is a remarkable fact, that people generally regard the waste of water as totally different from the waste of any other article. The consensus of opinion on the part of all, who have given the subject attention, is that waste and not use is chiefly responsible for the leaps and bounds of water consumption, and that the waste may be curtailed, often to the extent of cutting the consumption in half, by proper control of the supply. Unnecessary and preventable waste has ruined many a Water Work, and has been proved to be the principal cause of water famine in most cases, while the conservation of water wasted, would be the means of enormously increasing the resources of the Municipalities generally or relieving the strain arising every season drought, and affording a surplus, sufficient

to meet the needs of many portions of the town neglected, or that go practically with pipe water.

In this connection, We are induced to quote here poignant remarks of Mr. Brush, an eminent Water Engineer:—"Perhaps the greatest folly of the times is the almost universal attempt of cities and towns, to increase their water supply plants to keep pace with their waste. It is a hopeless task. The amount of water that can be used has a limit, the amount that can be wasted has no limit."

It is of the utmost importance that the campaign should follow a definite system, *viz:*—

(1) House fittings.

(2) Services from the stop taps to and in houses.

(3) Stop cocks or taps.

(4) Services from the water mains to the stop taps.

(5) The water mains themselves.

From the above, it would seem that all the detection necessary can be carried out without installing meters at all.

The Water Engineers, in charge of Waste Prevention and Detection Branch should have an accurate plans of the mains in their districts, and it is not until they have to shut off, the whole of their mains, one by one individually that they realise how incomplete the plans are. The next step then is to put their "House in Order," *i.e.*, "Waste Water Areas or Districts," this may be divided into 3 sections.

(1) Complete plans of all visible street valves; hydrants, air valves, scour valves, etc., and testing of the same.

(2) Unearthing of buried valves shown on plans.

(3) Investigations of "Cross Overs," and other points, where different supplies meet.

Dealing with this seriatim:—(1) *Visible Surface Boxes*:—This, of course, is a simple procedure, but great care must be taken, in testing the fittings to ascertain, whether they are in proper working

order, leakages, etc., or not. The most simple means of testing is illustrated by the Fig. 11 below:—

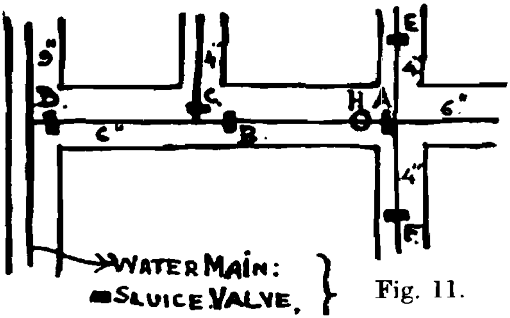

Fig. 11.

The sluice valves A & B are to be tested, and these are closed off, and the Hydrant (H) opened, water will usually be emitted, due to the "Head" in the main, from one point to the other. If, however, the pressure of water continues, one of the sluice valves is defective, and which one may be found by closing first valves E and F, and observing the effect at the hydrant, if no improvement is shown, valves C and D should be closed, and if the pressure disappears in the hydrant, the sluice valve "A" is obviously defective. This practice and procedure should be carried out throughout the whole district.

(2) *Unearthing of buried valves, etc.*:—Electrical instruments are used, which will detect the presence of a metal surface box, which is buried anything upto 15" below the road surface, and with a little practice to train the ear. If the stethoscope, and the memory of the oldest employee fail, it will be found more economical to use the electrical instruments, and to insert a new valve in the most convenient position, and thus to make saving of excavation in many places.

(3) *Investigations of Cross Overs, etc.*:—In most towns, the Water Engineers have the choice of supplying any particular district or street from either of two feeds, and it is at the junction of these

feeds, that the Engineer is often misled. Let us take one example:—It was believed to exist with the valve, say "B" controlling 5″ branch only and "A" say 8″ branch and 5″ main with an unfound valve "C" on 8″ branch only. But, actual testing proved that this was say wrong, because it showed that the valve "A" controlled 8″ branch, but not 5″ main and that "B" say controlled both 5″ main and 5″ branch, while A and B were closed, all the three water mains were shut off. The waste of water can usually be traced out into three distinct causes:— (1) Leakages in the distributing mains, and sub-mains (2) Leakages in house connection and fittings and (3) Waste by consumers leaving taps running.

Regarding section (1), Mr. Buckley, Chief Engineer, and Mr. Silk, Sanitary Engineer, Bengal, after making a systematic investigation on the subject of Wastage of Water in Calcutta, submitted a report in 1901, in which they asserted that the leakage in the larger mains alone was considerably greater than 22% of the total supply, and this loss is not peculiar to Calcutta, but other town also sustain a similar loss. Noticed that section (2), being by far the largest, when the waste arises from defective fittings, the only course left is to inspect the premises where such defect is suspected; but a large number of houses will often be visited, before the actual waste is discovered, thence the great difficulty and expense attending waste detection. Where waste results from a burst in main or pipe, this evil is soon discovered, as the water will work its way out to the surface, but it must be noted that the increased use of asphalt for roads, nowadays, with their underlying bed of impervious concrete, tends to prevent leakages showing at the road surface to a very large extent. In sandy soil, also, the leaks are very difficult to detect, and require careful examination of the ground, and perhaps opening of a long length of pipe. When leaks occur in pipes

under pavement or tar macadam road, they frequently follow the pipe discharge into an underground sewer or drain, and remains undetected for years. It is done only by carefully metering the amount of wastage through leakage which can be estimated, and a proper and water-tight condition of mains can be maintained. The discovery of such serious leakages is due to the reports of the falling pressure in the mains. With regard to the waste from leaky mains, American Water Engineers generally assume, a maximum allowable leakage of 50 to 70 gallons per mile per inch diameter of pipe. The best time for detecting the waste is either late at night, or early in the morning. At such periods there will be no draught on the service pipes, if the latter and the fitting are in good order. Any water passing through the service pipes will, in all probability, be due to waste. The best remedy for section (3) is that of measuring the water supplied by meter to each individual water-taker, and obliging each individual to pay for the quantity of water used and wasted, both. We would quote from a very able article read by Mr. William Schoenheyder, before the Institution of Mechanical Engineers in February 1900, the following small table, wherein leakage through comparatively small holes, under pressure of 100 feet head, are shown:—

Table 5.

Diameter of hole permitting leak.	Discharge in gallons.		No. of persons that wastage would supply	
	Per Hour.	Per 24 Hours.	at 15 gallons per head per day.	at 30 gallons per head per day.
1/4" ..	381	9144	610	305
3/16" ..	214	5130	342	171
1/8" ..	95	2280	152	76
1/16" ..	24	567	38	19
1/32" ..	6	144	10	5

From the above Table 5 it will appear that the quantity of water lost through $\frac{1}{8}$" hole under 100 ft. head is sufficient to meet the requirements of a fairly big village containing 1,000 population. This is shown graphically in the following, *Figure No.* 12.

One drop per second	1 Minute	loss	is 1/10 ounce
	1 Hour	"	" 6 "
	1 Day	"	" 9 pints
	1 Week	"	" 8 galls
	1 Year	"	" 416 "
Two drops per second	1 Minute	loss	is 1/3 ounce
	1 Hour	"	" 20 "
	1 Day	"	" 3 2/3 galls
	1 Week	"	" 26 "
	1 Year	"	" 1352 "
Drop breaking into stream	1 Minute	loss	is 2 ounce
	1 Hour	"	" 1 gall.
	1 Day	"	" 24 "
	1 Week	"	" 166 "
	1 Year	"	" 8736 "
1/16" Stream	1 Minute	loss	is 7½ ounce
	1 Hour	"	" 3½ galls
	1 Day	"	" 84 "
	1 Week	"	" 588 "
	1 Year	"	" 30576 "
1/8" Stream	1 Minute	loss	is 23 ounce
	1 Hour	"	" 11 galls
	1 Day	"	" 260 "
	1 Week	"	" 1820 "
	1 Year	"	" 94640 "
3/16" Stream	1 Minute	loss	is 39 ounce
	1 Hour	"	" 18 galls
	1 Day	"	" 432 "
	1 Week	"	" 3024 "
	1 Year	"	" 107248 "

Fig. 12.

The leakages in mains and sub-mains are constant sources of waste, specially when the defects are underground. The waste takes place through leakages from bad caulked joints disturbed by irregular settlement of mains and sub-mains from fracture of mains and sub-mains, due to the same

cause, and also at times from blown joints. The first essential of a Water Waste Detection campaign is:—

(1) Suitable Waste Detecting Inspectors.

(2) To seek the co-operation of Local Plumbers, and the general public, and this may be done by means of a circular letter to the house holders, informing them of the office intention to reduce the wastage of water in the town supplies, and asking them to assist by having all faulty fittings repaired; the inducement of free washers on supplies direct off the main, together with a list of plumbers, who will carry out the repairs, etc., will surely result in a considerable saving to the Local Authorities, Municipalities or Water Boards, etc., as the case may be. Moradabad, Aligarh, etc., Water Works are run by the private Water Companies.

(3) A house-to-house inspections of all water fittings by sounding also, after 3 days, the service of a leak or waste notice, which should be followed up by re-inspection to see that it has been complied with. The good results of house-to-house inspection for locating invisible leaks, which may exist in the buried pipes of storage tanks, can be obtained at some time, between say, 1-30 a.m. to 4-30 a.m. when the supply storage tanks have been replenished, after the day's draw off. It is important to note that a leakage in the main itself will usually be detected on several stop taps, whose ferrules are in its vicinity. This house-to-house inspection system of inspection has been discarded in Leeds, for many years. Sounding on the outside stop taps having been substituted, which allows of a waste water district or area being covered at a much quicker rate, than by the entry of all the premises, without any loss, but rather a gain, in efficiency.

Bibs Taps—Maintenance and Rewashering:—Taps, which do not shut off properly must be made good, and where the fault is in the washer, the rewashering of both, hot and cold taps, should be carried, out, free of charge, on notice being given to the Waste Water Department, or to the District Inspectors on their rounds. The use of rubber washers is not recommended, as they are found in wear to be a prolific source of noise (i.e., water hammer). People got into the habit of sending down to the Water Department Office for a man to repair their taps, and of doing nothing until he turned up, even if several hours had to elapse. The public were liable for this wastage, they ignored the point, and would not send for a plumber. Waste detection is a job that never ceased. All Water Engineers had their difficulties, some peculiar, perhaps to the districts in which they worked, but water waste is a problem affecting them all.

Methods of Detecting and checking waste, are as follows:—

(1) Limiting the number of taps in each individual premises.

(2) House-to-house inspection.

(3) Metering every house connection.

(4) Replacing old pipes and fittings, after 15 or 20 years of age, as the case may be.

(5) Notices to owners to repair the leaky plumbing fittings, etc., failing which the Court action should be taken.

(6) Waste water meter system.

Regarding No. (1), it has been found from experience that greater the number of taps allowed in any one premises, greater becomes the uselss wastage of water in that premises. This fact has been recognised and followed also by the Water Officials of many places, say for example, the Bombay Municipality and the number of taps to be allowed

in any one premises, under a certain scale, and thereby they have been able to check the waste to a palpable extent. For example, a property consists of ground with three upper floors, and fully occupied on the block system, with a valuation of say Rs. 3,000 then the number of taps permissible under the Bombay Municipal Water Bye-Laws (for regulating all methods and things connected with the supply and use of water) are 3,000 divided by 300 (a constant figure) = 10 taps. There is another rule, which also contributes largely in reducing the waste through defective fixtures and fittings, and it is this, that no house owner is allowed to get more than one water connection for his individual house. (Strictly observed by Hyderabad State, Patna, etc.). The size of water connection (according to the Bombay Municipal Water Bye-Laws) is based on the area of the floor, or the combined area of the floors excluding terrace floors of the building to be served, and will be in accordance with the following Scale:—

Floor area in square feet	Size of connection
From 1 to 2000	½" (internal diameter)
„ 2001 to 5000	¾" „ „
„ 5001 to 10000	1" „ „
„ 10001 to 18000	1¼" „ „
„ 18001 to 30000	1½" „ „

The size of the ferrule and the number of taps admissible for domestic, etc., purposes as per House Connection Rules, sanctioned by Government, under Notification No. 4468-L. S. G., dated 15-8-1922, and taking the Patna-Bankipore Joint Water Works Committee, under No. 5422—L. S. G.—framed the following Rules, and approved by the Government of Bihar and Orissa, in any holding shall not exceed the following:—

Annual Valuation	Diameter ferrule	Number of ½" taps not more than
Below Rs. 150	⅛"	1
From Rs. 150 to Rs. 299	3/16"	2
" " 300 to " 449	¼"	3
" " 500 to " 999	5/16"	4
" " 1,000 to " 1,500	⅜"	6
Above Rs. 1,500	½"	8

The additional taps are allowed, and the size of the ferrule increased by the Superintending Engineer, Public Health Department, in special cases only.

A novel method of calculating the quantity of water required in various parts of the distribution system was devised by Mr. W. W. Brushing in connection with Water Supply of New York, and consisted in using the Floor area of the buildings in the district as a basis instead of the population. This is the easiest, safest and the quickest method found suitable in practice.

(2) House-to-house inspection is an effective method to reduce the preventable waste of water in the consumer's premises. The application of the method is attended with some inconvenience to the householders, who naturally resent the frequent entry into their houses by the waste preventing Inspectors. By this method, a very large reduction in the consumption of water has been effected in several towns in England, notable in Manchester, Glasgow, Newcastle and Cambridge, where such inspection is in vogue. This sort of inspection reduced the waste that proceeds from taps and cisterns inside the premises only. It was adopted both in Europe, India and America, and proved to be fairly successful. It did not, however, improve the situation very much, as a poor fixture could not be converted into a good one at the bidding of an

Inspector, nor were the consumers likely to be as careful to prevent water from running to waste, as when an Inspector was paying his visit.

(3) Introduction of thorough scheme of metering, and of payment of water taxes, according to quantity consumed has been found to be in America, England, and in some parts of India, the best means of checking preventable waste of costly water. An interesting comparative towns, showing the general effect of metering is given in the Boston Water Report, from which the following facts are taken. Twelve cities and towns are taken, where meters are in general use, Lowell, Milwanter, Fall River, Providence, etc., and the consumption is shown to average 60 gallons daily per capita. Against these another twelve cities and towns are taken, as Cambridge, Baffalo, Salem, New Haven, etc., of population, locality and trade similar to the first named twelve, but where very few meters are used, and the consumption in the latter averages 175 gallons —very nearly three times that of the former.

The general practice with the Water Engineers is to provide for a daily consumption for all purposes of 30 gallons per head. Opinions differ as to the right standard per head for domestic use is somewhat difficult to obtain reliable data for it. The authors are of opinion that the consumption of water for domestic purposes, should not exceed 20 gallons per head per diem, and any community consuming over 25 gallons per head per day for all purposes, except trade supply, is guilty of waste or mis-use of water in one form or another. It is a source of loss to the public in two ways. (1) It needs a large supply of water than is just necessary. (2) It necessitates the use of larger pipes, etc., which is also a loss in money. The following figures of average daily supply in gallons per day per head of population distributed for all purposes, serve to show how the quantities vary in different towns:—

English Towns		Indian Towns		
Leeds	45	Calcutta	(1935) ..	39
Liverpool	25	Madras	(1935) ..	32
Glasgow	54	Jamshedpur	(1931) ..	50
Rome	200	Rangoon	(1931) ..	100
Berlin (wholly metered) ..	16	Simla	(1934) ..	10
		Patna	(1935) ..	18

Meters for measuring water under pressure may be positive or inferential. The great difficulty with positive type of meters such as Frost; Taylor's duplex; Kent's absolute; Kennedy's Patent, Beck's Imperial and American, Worthington, is to alternate the flow of the water, and measure the actual quantity of water passing with certainty, and avoid leakage of water slipping by, and at the same time to reduce the friction to a minimum, so that no sensible resistance may be offered to the passage of the water to retard its velocity, and reduce the head or the pressure. The inferential meters are those of rotary type, and this meter is constructed upon the well-known turbine principle or Barker's Mill. Siemen's and Adamson's (made by Messrs. Guest and Chrimes) Taylor's; Watch Dog; Helix meters are of the inferential types, and chiefly manufactured and used in the United States. Their merit appears to be simplicity and small size and lightness. Those interested in the question of Meter supply, the Authors strongly recommend a very able article appeared in "Engineering" on 2nd and 9th February 1900, by Mr. William Schonheyder, entitled "Water Meters, with special reference to Small Flows and Waste in Dribbles."

The enormous number of meters that would be required to meter all the services in fairly big towns like Madras, Calcutta, Hyderabad (Dn.), etc., would involve a very huge outlay, which only a few Municipalities in the present state of their finances, would be able to incur. The best safeguard against waste and the consequent loss to the funds of the local authorities is the selling of the water by meter measurement.

The real test of the best management of Water Works is the percentage of water that can be accounted for. This should be in the region of 90%. Towns like Hathras, Kasi, Jaunpur, where practically all the service connection are metered; whereas the larger towns like say Hyderabad, Lucknow, Cawnpore and Agra can account for only 45.35; 41.69; 60.56; and 47.5 per cent. respectively. As a rule, the percentage of unaccounted for water is within 10%, and so these Water Works may be taken to have solved fully their problem of waste by wholesale metering.

This is done by passing the supply of water to the consumer through a meter, which consists of an arrangement of mechanism of such a character that the quantity of water passing through is recorded. The motion of the water drives a train of clock-work, and the latter moves an index arm, which points out on a dial the number of gallons passed through. The immediate result of the use of meters is that the consumer looks very closely after the state of his fittings, and does all he can to check waste of water, because the cost of the waste of water comes out of own pocket, and not out of that of this fellow ratepayers. The Authors from their experience state that the greatest portion of the waste ooccuring in any town takes place in the bath-rooms, and water-closets of wealthier classes, and at the chawls of the poorest classes. Apart, however, from this, a great deal of leakages takes place simply because it is difficult to appreciate how large a quantity of water is lost on account of an apparently very small leakage continuing through the whole 24 hours. It would astonish most people, who see water merely dripping from a tap, or from a leaky pipe, to be told that the loss is very likely from 13 to 20 gallons in 24 hours, or fully the average consumption of water of one individual. Take for instance, Figure 13. Through each hole, the flow under a constant pressure of 45 lbs. was separately and carefully measured, and the illustration shows the number of gallons per

- LEAKS. -

THE FOLLOWING TABLE WILL SHOW THE APPROXIMATE AMOUNT OF WATER WASTED FROM APPARENTLY INSIGNIFICANT SIZE OF LEAKS OR DEFECTS, AS FROM WATER MAINS, SERVICE PIPES, FITTINGS ETC.

Fig. 13.

SIZE OF THE HOLES	ACTUAL SIZE OF LEAKS OR DEFECTS	UNDER 45 LBS. PER SQUARE INCH PRESSURE (3)			AT THE RATE OF 15 GALLS. PER. HEAD PER DAY THIS QUANTITY WOULD SUPPLY	ASSUMING THE TOTAL DAILY SUPPLY TO BE 30,000,000 GALLONS OF WATER, THE NUMBER OF SUCH LEAKS REQUIRED TO PASS WHOLE OF THIS QUANTITY OF WATER AT THE PRESSURE STATED WOULD BE	FROM "PRACTICUL HYDRAULICS" BY THOMAS BOX — UNDER PRESSURE OF 45 LBS. PER. SQ. INCH (6)		
		DISCHARGE IN GALLS. PER					DISCHARGE IN GALLS. PER.		
(1)	(2)	MINUTE	HOUR	24 HOURS.	(4)	(5)	MINUTE	HOUR	24 HOURS.
SEWING NEEDLE OF ORDINARY TYPE		·125	7½	180	12 PERSONS	166,666			
HOLE 1/64" DIA.		·25	15	360	24 "	83,333			
" 1/32" "		·45	27	648	43 "	46,296			
" 1/16" "		2·66	160	3840	256 "	7.812			
" 1/8" "		3·20	192	4608	307 "	6,510			
" 1/4" "		7·50	450	10800	720 "	2.777	9·6	576	13,824
" 1/2" "		36·66	2200	52,800	3520 "	568	38·4	2304	55,296
" 3/4" "		75·00	4,500	108,000	7200 "	277	86·4	5184	124,416
" 1" "		135·00	81,00	194,400	12,960 "	154	153·0	9180	220,320

{FROM ACTUAL EXPT. MADE BY THE LIVERPOOL CORPORA- -TION (ENGLAND)}

day, which passed. The test carried out by Mr. William Hope, A. M. I. C. E. The annexed Figure 13, is taken from a paper of his on the subject of the "Waste of Water" (proceedings of Institution of Civil Engineers, Vol. XC, session 1891-92, Part IV). This interesting paper has been published in pamphlet form, and should be read by all, who are interested in the question of the prevention of waste of water, and is described as:—"A lead pipe drilled with various sized holes, the burr on the inside not being removed. The actual number of gallons per day which passed through each hole under a pressure of 45 lbs. per sq. inch is noted together with the corresponding number of persons that quantity would supply at the rate of 15 gallons (or 2½ c.ft.) per head per day, 43 persons.

This matter of the waste of water in houses is of much greater importance, than that of waste from the mains of the Water Works. These mains are constructed by, and are under the supervision of those whose evident interest is to prevent leakage from them, and such leakage is kept within small limits without very much difficulty.

(4) *Replacing all pipes and fittings*:—It is found on examination the pipes and fittings due to the old age or inferior quality used, have become seriously corroded or damaged, then this replacing of all such pipes and fittings should be taken up in hand immediately. Such replacing of pipes and fittings defective will invariably be followed by excellent results. The best example for this is Norwich, given by the Professor, G. E. Canham, F.I.S.E., R.P. The consumption of water was 40 gallons per head per day, but after the defective pipings were replaced by one of superior and heavy quality, the consumption fell to only 18 to 20 gallons per head per day.

(5) *Penalty for causing waste of water*:—Water waste in any form should at all times be carefully

avoided, and the consumers should know that the water waste or mis-use of water renders them liable to prosecution and on conviction to a fine not exceeding $5 in the terms of Water Works Clauses Acts.

(6) *Waste Water Meter System:*—The Waste Water Meter System of inspection has been found in practice to be an effective, and sure means of detecting leakages, whether above or below ground. The great advantage of the Deacon Meter is that, it enables a much smaller staff of Waste-preventing Inspectors to satisfactorily perform the duties, since it at once attracts special attention to, and indicates from which particular cause the waste arises.

Fig. 14 shows the general form of the meter within a casting socketed upon line of main, is fitted a gun metal tapered tube (B) (within which a gun metal disc is suspended by means of a wire passing through a packed gland, and connecting a small carriage for pencil moving vertically between guides) through which the water passes as shown by the several arrows. Guided vertically within the tube is a gun metal disc (C) of such size as to fit the smaller end of the tapered tube. From the upper end of the stem of the disc, a fine wire (E) passes through a packed gland (F), to a small carriage (G), guided vertically and carrying a pencil. From the carriage, a cord passes over a pulley (H), to a counter balance weight, whose tendency is to keep the disc at the top of the tapered tube (B). The diagram paper is carried upon a drum (K), which is caused to rotate by clock-work (J), once in 24 hours, or by special arrangement of gearing it may be made to revolve once in 6 hours or less for night inspection. ?

The Deacon Meter consists in the use of a water meter of peculiar construction, and is largely used

throughout Great Britain, and in this country by Corporation and Water Boards for detecting hidden and underground waste of water.

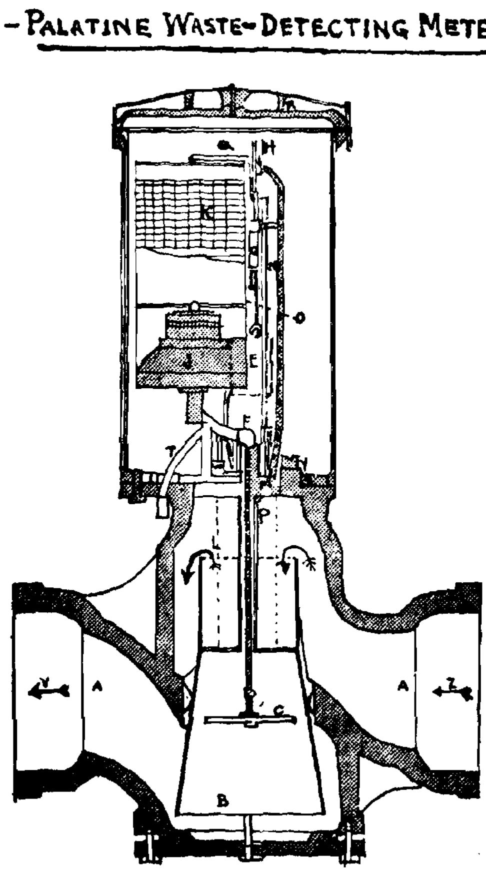

Fig. 14.

NAME OF PARTS

A-Cast-Iron Body. B-Brass Gauge Cone. C-Brass Disc. D-Disc Stem. E-Hard Brass Wire, Connecting Disc Stem to Pencil Carriage. F-Gland with Phosphos Bronze Bushes. G-Metallic Pencil and Frame. H-Pully carrying the Balance Cord. I-Balance weight. J-Lever Clock. K-Drum carrying the Diagram Paper. L-Guide blades. M-Clock bracket Forming Cover to Meter Body. N-Standard to carry Pulley and guide the Pencil Frame, O-Flexible Balance Cord. P-Disc Cap. Q-Hinged Pivot for top of Drum. R-Meter Box with Air-Tight Cover. S-Hydraulic Packing Ring of India Rubber. T-Drain Pipe. U-Screw for Fastening the Clock. V-Relief Plug, W-Cap Nuts. X-Bottom Cover. Y-Outlet Socket. Z-Inlet Socket.

The Theory of the Deacon Meter's Action—When the flow of water is passing through the Deacon meter, the disc is forced downward into the larger area, to an extent proportionate to the quantity of water passing, and the pencil is at the same time carried to a corresponding point on the diagram paper. The latter is ruled horizontally for gallons per hour, while the pencil moving vertically records the quantity passing. The drum and paper revolving cause quantity to be recorded at the right time.

Suppose, for example, that the rate is 500 gallons per hour, the disc will descend until the annual space, between the disc and the cone, is just sufficient to allow water to pass at this rate, and so on for any other rate of flow. It is therefore clear that as the disc descends, the water way is increased, and *vice versa*, and it will be found that for any stated flow, there is one position and one position only, in which the disc will rest. Consequently, if any increase or decrease of the flow takes place, it is accompanied by an immediate change of position of the disc. To put a Water Supply under this meter system, it is first necessary to plot out the various districts to be controlled by each meter.

Isolating Districts:—Each Waste Water area or district should be isolated by Sluice Valves, in such a way that the whole supply to the Waste Water District passes through the meter. The diagram below shows a District simplified in order to explain the Waste Water System.

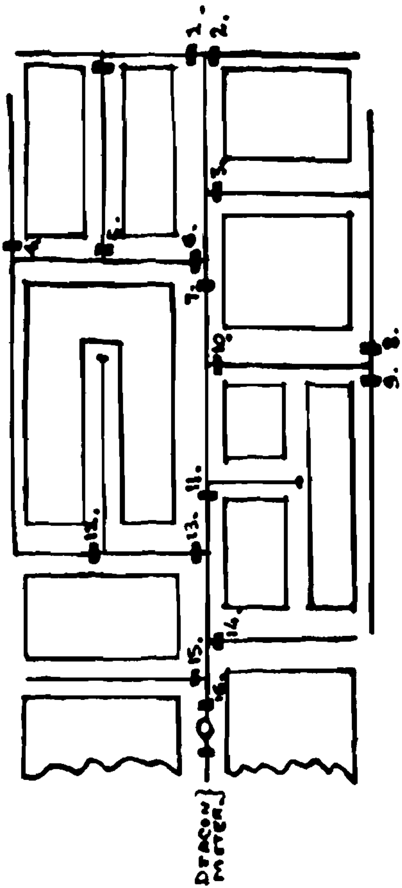

Fig. 15.

The Deacon Meter should be fixed close to the Sluice Valve direct on the water main, resting on a flag and a brick chamber built round it, which should be drained to avoid flooding. An arrow is cast on the body showing the direction of flow. It is also very important to set this meter quite vertical.

Capacity of these Meters:—The most convenient size of each district is found by practice to be:—

For	3"	main	class	A	meter	..	1200 to 1500 persons
„	4"	„	„	D	„	..	1500 to 2000 „
„	5"	„	„	G	„	..	2000 to 2500 „
„	6"	„	„	N	„	..	2500 to 3000 „
„	7"	„	„	P	„	..	3000 to 4500 „
„	8"	„	„	Q	„	..	4500 to 6000 „
„	9"	„	„	R	„	..	6000 to 10000 „

Palestine Waste recording Meters are used for the following reasons:—

(1) To ensure systematic waste detection.

(2) To obtain accurate records of leaks and night flow.

(3) To prevent the misappropriation of water.

(4) To conserve water supplies.

(5) To employ Inspectors of the best advantage.

There are two standard methods for the Detection of leaks in the Water mains.

(1) *Using Deacon's Waste Water Meters and also Stethoscopes, (Mr. W. Booth-Bryan)*:—A novel system has been introduced by Mr. W. Booth-Bryan and for detecting leaks on a particular service, which so far as proved more successful than anything else. It is simply the employment of a small "Bye-Pass" of ½" or ¾" diameter, spanning an ordinary sluice valve. This sluice valve on the service main supplying 50 houses more or less, and in some cases 100 houses, is shut, and the by-pass opened. it is known how much water will pass through the by-

pass, and that, it is sufficient for all the needs of the consumers. If then complaints of insufficient supply are made, it is evident that there must be either waste or leakage, and so a visitation is made to all the houses. If the fittings are good, there must be a leak somewhere, and the site can generally be ascertained by Sounding, *i.e.*, by listening with a Stethoscope at various points.

(2) *Method introduced by Mr. James William Restler:*—Leakage is localised in the following way with a limited number of staff. Between the hours of midnight and 5 a.m. (when it is assumed that no supply of water be required), each of the cocks commanding the branch pipe, leading to the side streets is shut, at a time agreed upon. The following morning diagram from the Deacon Meter of the Waste Water Area or District is returned, and it is then seen at a glance (by comparing the diagram and the time sheet), in which street the leakage exists. In order to show its exact position in the streets, a further inspection is made on the following night or day. This is confined to the particular. street. The small stop cocks on the house service pipes are in the first instance all shut off, and the Waste Preventing Inspector then applies a steel bar, *i.e.*, Stethoscope, (the old method, but it is the best from the practical experience) to the various mains cocks of sluice valves, hydrants, etc. By carefully listening, the Waste Preventing Inspector can from sound (*i.e.*, the hissing noise) made by the escaping water, determine with very great accuracy the position of the leakage.

The great advantage of this system of night inspection, preceding the day inspection, is that it enables the waste in a district to be quickly dealt with by confining the attention of the Inspectors to places where leakages are actually taking place. It is also unnecessary to send the Inspectors into the premises, where there is no wastage of water at all.

Many towns in Great Britain alone, including London, have been greatly benefited by the introduction of the Waste Water Meter System of inspection.

Bombay Practice of detecting underground and aboveground Wastage of Water is by means of the permanent Deacon Meter, wherever such meters are fixed in the districts, and the other Waste Water Districts by portable Deacon Meter, where there are no such meters fixed on the mains. The water mains are tested between 3" to 15" in sizes. The water connections on the mains to be tested in the districts are registered in "Inspection Book" beforehand. After the diagram (diagram is ruled with vertical hour lines, and horizontal quantity lines representing gallons per hour) is fixed on the drum of the Deacon Meter, which is then fixed on the clock that rotates with the pencil mark registering the water passing through the pipe, but by an examination of the index hand, the *motion of water can be divided into two kinds, the one being intermittent, and due to the opening and shutting of taps, and the other steady, and generally due to waste.*

After fixing of the Diagram in the meter as mentioned, each of the stopcocks commanding the branch on pipe leading to the side streets is shut at a time agreed upon. During the closing of the connections, they are also sounded carefully to ensure, whether there is any hissing noise due to wastage, by applying the stethoscope to each and every stopcock; hydrant; sluice valves; and other appliances connected with the water mains, to which access can be had from the surface of the street or footpath, a practised ear can only in the silence easily distinguish the sound of water escaping from a defect, or flowing through the communication pipes. If the Inspector hears water flowing through or adjacent to any stopcock (attached to a communication pipe), he closes that cock, and this observation proves a flow of water at a

particular house to continue and if this be so, it will indicate that a leakage exists between the stopcock and distributing main itself. If the shutting of the stopcock cuts off water flowing into the premises supplied through the communication pipe, the quantity so cut off is at the same moment indicated on the stop taps, on which noise has been heard, have been closed, the diagram on the meter drum is examined, and if there is still a considerable quantity of water flowing into the district, further examinations are made, and the surfaces of the streets over the mains are sounded to detect any underground leakage that may be taking place. The number of hidden underground leakages that are discovered by the above mode of sounding is remarkable.

When water is passing through a main and supplying nothing, but leakages, the flow of water is necessarily uniform, and any instrument which graphically represents that flow as a horizontal line conveys to the mind a full conception of the nature of the flow, and if, by the position of that line between the bottom and top of the diagram, the quantity of water is recorded, we have a full statement of not only the rate of flow but of its natures. It is known in short, that the water is not being usefully employed. Thus, while nothing but leakage occurs, the uniform horizontal line is continued. If now a tap is opened in a house connected with the main, the change of flow in the main will be represented by the vertical change of position of the horizontal line, and when the tap is turned off, the pencil will resume its original vertical position.

Distribution System:—The proper maintenance of distribution pipes, comprises Detection, Prevention and Repair of leaks, regulation of pressure to meet the requirements of the different parts of the Town or Ward, as the case may be, and the removal of deposits and extraneous growth within the main.

The Waste Water Meters should be installed at various strategic points in the Distribution System and all supplies should be metered at the commencement of the supply.

Stethoscope or Sounding Red:—The most effective instrument used for the sounding and detecting the hidden and underground waste, proved to be a Stethoscope consisting of a brass tube with a solid brass rod inside it, and a Mahagony head around diaphragm. It was found that Electric Stethoscopes were unreliable, and not of very much use, as they picked up a lot of extraneous noises. The soil around the water main had an effect on the sensitivity of a Stethoscope, and it is generally difficult to detect the waste sound with certainty in some soils. The electric leak locators are being too easily affected by wind and weather. *It was the experience that a practised man with a good ear could do nearly everything, that an indifferent man with an electric instrument could do.* The Authors have found too (particularly in Naigum Cross Road Waste Water Areas), that *it was often easier to detect a small squirt of water than to locate a burst in a main.* Authors have seen the bottom blow out of a main, and the water pour away without any sign on the road surface, and very little or no noise. *The sounder may often be misled by the "Waste" noise or sound, which varies in intensity according to its position, and not to its size, such as a pin hole leak in the service close to the fittings, on which the sounding rod is placed or impinging on the underside of the road foundation, will have far greater intensity of sound than will a substantial fracture in the under side of the water main midway between two sluice valves, and the hydrants.* In small Water Supply Schemes, where there are no Waste Detecting Meters on the water supply mains, then the easiest and less costly method to adopt for investi-

gating the hidden wastage of water by going right through the Town Water Supply systematically with only the Stethoscope. To detect the motion of the water in the pipes and mains, the sounding rod or the Stethoscope is used, and if there be motion in the pipe to any great amount *i.e.* "the hissing noise," the vibration will be transmitted to the stethoscope, and may be detected by applying the ear to the latter.

The noises heard and found everywhere, while Sounding the water mains of the City, and the Waste Water Officer should be able to differentiate between the noises transmitted by defective pipes and fittings, and noises of water flowing in pipes, and through the regulated sluice valves.

The Views of Capt. Munn's in his paper "Underground Water Resources" and on "Water Finding" will probably find wide acceptance amongst Hydrologists in the near future. His tips for location of underground water, based on sounding and sound common sense, and keen observation, constitute a safe and practical guide for those in quest of water. As Special Officer in charge of the Well Sinking Dept. Capt. Munn had to face many practical problems from day to day. The results of his researches applied, and found successful, constitute an important contribution on the subject of Practical Water Supply.

The following Methods far the Detection of Leaks are commonly adopted—

(1) Direct method or direct observation.

(2) Use of water stethoscope aquaphone, detaphone, sonoscope, etc.

(3) By the construction of a hydraulic gradient line.

The first can hardly be called a method, and is only practicable in places, where the soil under which the pipe is laid, is such, that leaks appear on

the surface. Second method of localization is by stethoscope aquaphone, dectaphone, sonophone, etc. Of these, *stethoscope and aquaphone, are essentially acoustic instruments, and leaks are located by following their sound.* The end of the sounding rod is placed over the pipe, and by listening with the ear against the rod, the sound of leak may be heard. *While in aquaphone, dectaphone and sonoscope suitable arrangements are made to magnify the sound, as in the case of telephone receiver,* but these instruments have generally electrical connections.

The third Method is that, if the pressure is determined at several points in a pipe line, when town supply is stopped, and pressure is maintained, the Hydraulic gradient can be plotted. If this is plotted through the points found by measurement, the Kinks in the Hydraulic gradient line will show the approximate position of the leaks, because of the change of direction of the gradient which should otherwise be uniform.

The water mains above 15" to 57" in sizes are sounded only late at night, to find the waste of water, if there be any by means of metallic Stethoscope or Sounding Rods as they are called. It is a metallic 3|8" W.I. tube to be fitted with the circular earpiece on top and 3ft. long, but this sometimes led to confusion of sound, as being too sensitive. The Authors have seen a Stethoscope with straight grained Salwood, used by Calcutta Water Works staff, after the pattern of those used by Doctor's in former days. Like the Doctor's instrument, this one also had a flat piece of thin wood on which to place the ear, and the result obtained was generally excellent.

Summary of Methods of Waste Prevention:— Method of preventing waste may be summarised as follows:—

(1) Distribution system is to be divided into blocks, supplying 2,000 to 3,000 population.

(2) Sluice valves are to be arranged in such a way that all branches and parts of mains can be easily controlled.

(3) Each block is to be supplied through a waste water meter.

(4) Night inspection for detecting and locating leaks is to be done periodically.

(5) Service connection and all works in connection with street mains should be done by only authorized licensed plumbers.

(6) All fittings should be of an approved specification, and stamped before use. Samples of all fittings should be kept in Water Works office for inspection.

(7) House to house inspection during day to examine the condition of fittings, and to locate leaks is to be done.

(8) Prompt re-washering of taps. Inspectors should re-washer all the taps on their rounds, when they find them leaking. This should be done free of charge.

(9) Metering every service connection, and charging the extra quantity supplied.

(10) The initial cost of meters should be paid by Municipality, and for subsequent maintenance and repairs, a quarterly fee may be charged. Only one or two types of meters, which have been found to be satisfactory, should be used in one work.

The cost of Waste Detecting Meters is learnt from inquiries (approximately) as follows:—

3″	..	..	Rs. 725-0-0
4″	..	..	Rs. 775-0-0
6″	..	..	Rs. 900-0-0
8″	..	..	Rs. 1,500-0-0
10″	..	..	Rs. 2,000-0-0

In connection, the general considered Opinion is that to keep the supply of a town within reasonable bounds, an efficient system of inspection is absolutely necessary, and that a systematic and effective inspection could be carried on at

a very moderate cost, which will be amply repaid in the value of the water saved, and that the useless wastage could be very much reduced by the introduction of a system of testing and stamping of all fittings, and that within certain limit, the expenditure incurred by the system of free repairs will be set off by the saving of water. Water, the value of which is often underrated should be supplied copiously, but not wastefully, apportioned with care, under just and wise control, having a single eye to the people's benefit.

In this Country, unfortunately no attempt has been made either by Municipal Authorities or Government Administrative Department to reduce the waste or devise means for its prevention. These Authorities believe that the service connections are only responsible for waste of water, and by the effective prevention of this alone, the problem of waste prevention will be solved.

In conclusion, it is very well to remember that the campaign against Water Waste is never finished, and the Water Engineer and the Operators must be patient and wise in retaining his trained operators, if they are suitable, even to the extent of employing them partially in other capacities.

This subject is treated *ab initio, i.e.* from the foundation to its finishing and furnishing, and the application, of methods of Detection and Prevention are given, so as to render the Local Authorities, etc., a valuable asset for the occupant. The Local Authorities have jurisdiction, in regard to the Prevention of Waste of Water. The Authors' main aim and object in writing out this work, is to enable the reader interested with this particular branch of Water Engineering, to understand at a glance what has been described. This work is the result of experience gained by the Authors in the Actual practice of Detection and Prevention of Water Waste in Town Water Supply

CHAPTER V.

MEASUREMENT OF WATER BY METER

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MEASUREMENT OF WATER BY METER

A well-known English standard dictionary defines the term Meter as an apparatus, in which the measurement of the quantity of water is obtained by some mechanical contrivance arranged to be moved by the water, as it passes along. The best safeguard against the wastage of water, and the consequent loss to the funds of the Local Authorities is the selling of the water by measurement. This is done by passing the supply to the consumer through the meter, which largely consists of an arrangement of mechanism of such a character that the quantity of the water passing through is recorded. The motion of the water drives a train of clockwork, and the latter moves an index arm, which point out on a dial the number of gallons passed through. There are various designs of meters to choose from but the aim of all is the same, *viz.* to record in an accurate manner the quantity of water actually passed through to the consumer. There does not seem to be any good reason, why better class-houses should not be supplied by meter, in the same way as manufacture is. Where the supply conducted in this way, the saving of water would be enormous in a town of even moderate size.

Measurement of Water:—Hydraulic Engineering practice necessitates the gauging of water, both in the several modes of its occurrence in nature.

The water meter apparatus coming under this subject, includes the trade and the domestic meters, which are essentially Waterworks fittings for the distribution.

The sale of water supply by meter system is one in which the water used in every house is charged for at a uniform rate, just as the gas is, the price being,

as a rule, from a few annas per 1,000 gallons of water consumed. There must be a difference in the rates for the water consumed for the domestic and the trade purposes.

There is also a little difference between this system, and the district meter system, at any rate, so far as the results are concerned. There is, however, a great difference. If the district meter system, be properly done, leakages can be detected and easily stopped but every inhabitant of the town is then free to misuse water to any extent that he likes, and there are always many who use water extravagantly, if there is no check on them, and the living examples of this system are big towns, like Calcutta, Madras, Hyderabad etc, where the enormous number of meters that would be required to meter all the services of fairly big towns, mentioned above, would involve a huge outlay. It is customary in fairly big towns to supply water by meter to the factories and other establishments, that use a large quantity of water, as Bombay. With the domestic meter system, every householder has to pay for all the water, either consumed or misused in his house, and he therefore, naturally inclines to do all that he can to prevent the misuse or waste. The introduction of thorough scheme of metering, and of payment of water-taxes, according to the quantity of water consumed, has been found to be the best method of checking the preventable waste of costly water. But, again with this system, there is the greatest evil from the Health point of view that the poorer people, who need particularly to be encouraged in the legitimate use of water, as it is with them that epidemics most commonly break out. To this, the advocates of the complete domestic meter system reply that the experience has proved that there is no harmful stinting in the use of water, when the people have to pay for it as for gas. It is stated, in a paper read by Dr. Macadam, before the Social Science Congress in

London, in the Year 1888, in support of the former view that diseases commonly attributed to the unsanitary and economic conditions, where the sale of water by Meter has been introduced. The diminution in the use of water arising from the introduction of the domestic meter system, will not result in an improvement of the health of the people, and also in the general sanitary condition of a town. In a discussion over the paper of the Meter System in the Institution of Civil Engineers (London), it was stated by the eminent Water Engineers that in a very few cases of Cities and Towns, where it was tried the saving of water did not cover the interest on the first cost of meters, together with the wear and tear, and depreciation. Then comes one more difficulty, which is that, in spite of all the ingenuity that has been spent on the matter, it can be said that the Perfect Meter has not yet been invented, that is to say there is no meter that has not some objectionable features, atleast when used in certain cases. Take the word of water meter makers themselves, that there is no meter approaching perfection. The general tendency of each maker is to condemn the production of every firm, but his own, without stint, generally giving good figures in support of his statements. Indeed, thorough metering has in its scope both the virtues of "Cure and Prophylactic".

The gradual introduction of the domestic meter system in Berlin, from the year 1865-1885, with the most marked success, gave a great stimulus to the sale of water in measured quantities. A paper read on "The Sale of Water by Meter" in Berlin, by Henry Gill, M.I.C.E. (Proceedings of the Institution of Civil Engineers, Vol. CVII), is interesting and worth a glance. From this, it is not to be concluded that, the system of thorough metering has been so successful in the case of Berlin, but it will be successful in all cases of Indian Towns. It was successful in Berlin, due to the principle of these being the fact of the existence of the flat system of residence.

Families with their servants, do not, as a rule live, in separate houses, but live each on a flat or part of a flat of a large house.

Whatever may be said on one side or the other, the fact remains that the adoption of the sale of water by the domestic meters has greatly increased on the continent of Europe, and its use is rapidly increasing in American towns too. The domestic meters appear to have found less favour in India, than in most other places. It is evident that the meter system is more applicable to the places, where water is cheap. Again, in connection with the high cost of meters, it is the practice that Municipalities or Water Companies supplying water should obtain power to supply water by meter, or to charge for it in proportion to the quantity of water consumed, yet should not "meter" a whole town, but take advantage of the privilege of selling the water by meter only in cases where, it is suspected that the consumption of water is much more above the average etc. Water rate is usually the value of the water actually supplied to a consumer in the premises for domestic purposes. This is not really taxation, but value realised for a commodity sold.

Peculiarities of Meters:—An ideal meter should satisfy the following conditions:—(1) To register correctly all water flowing through, from a dribble to the highest flow, (2) It must work under all conditions of pressure, without losing efficiency; (3) To absorb the minimum amount of head in working; (4) Cost of maintenance should be as low as possible (5) Easy to repair without disconnecting the body; (6) It should prevent back-flow passing through it, and it should not register, when no water is passing through it. The meter rent would prove, but a small burden to the consumers, and they would have the satisfaction of knowing that the amount of their annual water tax greatly depend on their care.

Water meters are generally tested for:—Sensitiveness, accuracy, and capacity. This meter in reality measures the velocity of water passing, and not its volume, and are of little use in measuring fine and intermittent flow. The objections to its using is: (1) Where there is liable to be air in the pipes. (2) While stopworking the water will continue to flow through the meter without registering. (3) Less accurate. The test for meters adopted in this country are not so elaborate; only the test of registration and accuracy are made by connecting the meter to the supply main and arranging it to deliver into a calibrated tank, with a gauge glass to show the capacity at different heights.

Meters are generally divided into 3 different distinct classes namely; (1) The Venturi Meters for measuring large supplies and for use on the water mains in general (2) The Positive type Meters and lastly (3) The Inferential Meters, for use on small branches and general trade supplies.

The inventor of Venturi Meters and Venturi Law was an Italian Philosopher G. B. Venturi, then Professor of Physics at Bolognia University, in 1796. Venturi Meter is a meter in a class entirely by itself, and is probably a far more accurate water measurer than a Weir, and this theory of it was discussed in the Principles of Hydraulics. This Venturi meter is fixed to measure the quantity of water supplied to the towns, etc. It is based on the "Principle of Velocity":—Throat Velocity $= \frac{A1}{A2} = \frac{\text{Throat Area.}}{\text{Large Area.}}$

The Venturi Law is, that water flowing through a pipe of diminishing area loses the pressure, which it exerts laterally as it gains in velocity. Consequently, water flowing through an expanding cone loses speed and regains, "Head." There would, therefore, be a difference of pressure between a point at the full area of the pipe, and at the point of the greatest constriction this difference is called the

"Venturi Head." The Meter itself consists of two parts, the Meter-tube and the Recorder. The tube is a part of the ordinary pipeline, and only differs from it, in that it presents for a short distance, a truncated reducing cone coupled by a throat piece, to an expanding cone. There is, therefore on moving parts, whatever in contact with the flowing water, and any interruption of the supply from such a cause is impossible, and is always placed within 1000', of the tube. The recorder or Register consists of a specially designed mercurial "U" tube, the two members of which being connected to the upstream, and the throat of the meter Tube respecttively. This brings in the element of the Venturi Head, and clock-work-gear by which, the mercurial "U" tube is surmounted, supplies the element of time. The connection between the pressure and time is established by means of a float resting on mercury in one leg of "U" tube and rack and pinion gear. Venturi Meter is well described by Mr. J. T. Rodda, in his Notes on Water Supply (Institution of Civil Engineers' Proceedings of 1906). To quote from his descriptions:—"It enables large bodies of water to be measured easily and accurately. It determines leakage of pumps, mains or reservoirs, and offers to water works, a means of determining accurately, at little cost, the quantity of water drawn and the quantity consumed."

By means of this Venturi Meter, a Water Engineer is able to at once ascertain the following:—(*1*) Exact quantity of water passed. (*2*) The regularity of the rate. A paper was read upon the Venturi Meter, before the British Association of Water Works Engineers, by Mr. Kent, at London, in their meeting in July 1897. This meter is designed for the measurement of large volume of water, and is patented by Mr. Clemens Herschel, an American, and manufactured by George Kent of High Holborn, who is also the patentee and the maker of positive rotary meters for trade and domestic purposes, and

reciprocating piston meters, etc. The purpose for which this meter is specially intended is to measure the total volume of water delivered by the trunk main to a system of distribution. It is a far more accurate water measurer than a weir. The large 18½ feet diameter Venturi meter is in use on Nira Canal near Poona.

"The Domestic and Trade meters will now be considered, one after the other," Positive meters:— The positive meters to measure the actual quantity of water passing with the great accuracy and are generally single or double or three cylinder meters. The great difficulty with this positive type of meters is to alternate the flow of the water, and measure the actual quantity of water passing with certainty, and avoid leakage of water slipping by, and at the same time to reduce the friction to a minimum, so that no sensible resistance may be offered to the passage of the water to retard its velocity, and reduce the head or pressure. It is a very difficult method to fulfil this requirement satisfactorily, and at the same time to produce a meter at a reasonable cost and of convenient size. The positive water meter acts much in the same way as a two cylinder steam-engine, as water enters one cylinder and raises the piston in it, and the other piston meanwhile descending in its cylinder and forcing the water along the service pipe, the necessary valves being positively actuated by the mechanism. The volume of each cylinder (usually from 3" to 6" in diameter), being accurately known, it is necessary to register the number of strokes in order to show the number of gallons passed. The registering is effected by a system of gearing, and shown on the dials. The positive meter is to an accurate extent, efficient piece of apparatus, and is used to a considerable extent, but it is rather more complicated than the simple inferential type meter, and needs somewhat more attention The other positive type meter acts on the principle of a disc reciprocating through an arch

90° in the spherical chamber. The volume swept out at each stroke forms a basis for the reading of the meter.

There are, however, several positive meters that work reliably. A comparison of their relative merits would not, it is thought, be advisable. It is proposed to briefly describe one only, and that too without prejudice. The example chosen has been fixed upon, because it is the positive meter with which the Authors were first acquainted, and it is Kennedy's Patent Water Meter (i.e. reciprocating piston type). The Measuring cylinder forms the base of the meter, and is fitted with a piston made to move watertight, an almost free from friction, by means of an india rubber ring between the surafce of the piston, and the cylinder. The piston-rod, after passing through a stuffing box in cylinder cover, is attached to a rack, which gears into a pinion fixed on a shaft, that actuates the indexing and reversing gear. A weighted lever (in a vertical position) is struck by a projecting arm on rack, as the piston and rack rises and falls, and is caused to fall alternately on each arm of a duplex lever, which moves the cock-key and directs the water either above or below the piston and to the outlet parts. The movement of the indexing gear gives a reading upon the dial or counter of the number of gallons passing the meter. The Kennedy positive meter is the best known and most accurate in this type. In this, the distance travelled by the piston-rod, measures the quantity of water. It is best in the sense that it is being correct at all speeds and pressures, irrespective of the water flows slow or fast. For accuracy of measurement, there is no doubt as to the superiority of this type of meter over the rest. The cost of this meter is 3 to 4 times the cost of an inferential meter.

The other well-known positive meters are:—Frost; Taylor's Duplex; Kent's Absolute; Beck's Imperial; and the American Worthington meter.

The following are the types of Positive Meters:—(1) Reciprocating piston, (2) Reciprocating piston, i.e. two cylinders type, (3) Rotary piston type.

Inferential Meters:—As its name implies works on a principle, which is not positive, but from which flow is inferred to be proportional to a certain quantity usually the number of revolutions of a small turbine through which the water passes. These meters are much cheaper in first cost, than the positive type of meter. There is practically nothing first in then to get out of order, and they need very little attention, and being small in size and handy are largely used. There are two forms of Siemens inferential Meters used largely in India, the English, and the German. In English, water enters a hollow rotating wheel through a central funnel, issuing by tangential passages into the casing surrounding it, as in Barker's Mill. To prevent excessive speed of rotation, vertical blades are attached to the periphery of the wheel, and act as a brake by the resistance of the water, causing an approximately constant ratio to obtain between the velocity of the flow through the meter, and the rate at which the wheel revolves. This form of meter reduces the pressure considerably, and the orifices are apt to become choked with solid matter, which interferes with the accuracy of registration.

In German Siemens Meter, these objections are obviated. It consists of a gunmetal brass or in large sizes C. I. cylindrical chamber, in which revolves a a fan with vertical spindle with four plane vanes symmetrically fixed at right angles to it. These fan vanes almost brush the sides of the chamber. Water from the supply pipe enters tangentially at the periphery of the fan, and impinges normally against the vanes, setting them in motion, and revolving with them in the chamber. The whirling water next passes into an upper part of the chamber, above the vanes, where its rotation is checked by a diaphragm,

it then flows away through the outlet. This meter gives correct results, except for small driblets, such as occur, when supply pipes deliver into the cisterns, through slowly acting ballvalves. In order to prevent small quantities of water flow passing through a large meter unregistered, a bye-pass pipe is sometimes placed round the main inlet, and outlet, and is provided with a meter of small size. When the velocity falls below a certain point, a weighted throttle valve closes the main-inlet, and the water is diverted through the auxiliary meter, which is more sensitive to small flows. The Taylor and Sporton meters closely resemble the German form of Siemens Meters.

The following are the types of Inferential Meters:—(1) Rotary fan-type (2) Rotary turbine (3) Venturi Metres (4) Waste water meter (5) Pitometer (6) Disc-meter. The inferential type of meters used largely for trade and domestic purposes are those of the Rotary fan type. A standard example of these is the Siemens and Adamson's Water Meters, and introduced in England in 1854, by M|s Guest and Chrimes. The meter is constructed upon the well-known turbine principle or Barker's Mill. The measuring medium, in this type of meter, consists of a drum working on an upright spindle. Water is conveyed by the conducting tube into the centre of the drum, and allowed to escape at three or more apertures on the periphery of the same, giving to it a rotary motion. At each revolution of the drum, a certain quantity of water is delivered, which is registered upon a dial by an indexing gear of wheels and pinions. This meter is made and adjusted with extreme care, and is exceedingly satisfactory in its working, and registering under varying conditions with a very small percentage of errors.

The approximate delivery of Siemens make in gallons per hour, is given by M/s. Guest & Chrimes in the following table. The lesser quantity is based

upon 50 ft. and the greater upon 150 ft. head. The table is as under:—

3/8"	will	deliver	from	150	to	250	Gallons	per	hour
½"	„	„	„	300	to	500	„	„	„
¾"	„	„	„	600	to	1,000	„	„	„
1"	„	„	„	1,500	to	2,500	„	„	„
1½"	„	„	„	3,000	to	5,000	„	„	„
2"	„	„	„	4,000	to	7,000	„	„	„
2½"	„	„	„	6,000	to	10,000	„	„	„
3"	„	„	„	8,000	to	14,000	„	„	„
4"	„	„	„	13,000	to	23,000	„	„	„
6"	„	„	„	27,000	to	46,000	„	„	„
8"	„	„	„	45,000	to	77,000	„	„	„
10"	„	„	„	70,000	to	120,000	„	„	„
12"	„	„	„	90,000	to	150,000	„	„	„

Another form of Siemens & Taylor's inferential meters, chiefly used in India, are of the fan type.

A few years ago, the city of Boston, U. S. A., appointed a Commission, to test the water meters. These tests were the most exhaustive, severe and costly, made with water Meters, extending over a year. 27 Meters were sent in for trial, and the only one, respecting which no complaints were made, no objections raised, no defects named nor any alterations whatever suggested, was "Frost's patent Positive Meter."

It is quite impossible to describe all the types of water meters, in existence and available for sale in the market, and their design is best left to the Specialists. What is really desired from the point of view of a householder, is a meter, which works noiselessly, because it must be remembered that water pipes are excellent conductors of sound. The disc type meters are cheap, accurate, of small weight and bulk, but after use for a short time, as 6 to 9 months, their accuracy is lost, and will not register at all at low rates of flow. This fault is one of the worst from the point of view of the Local authorities responsible for the equitable water rate

collection. It is therefore not desirable to purchase this type of meter. The best meter to select is one which has the least slip even if it does cost more money.

The accuracy and life of a meter depend largely on the friction on its parts, and since the water supply usually cost so much a gallon per foot of head or pressure, at which water is supplied, the frictional loss of meter is another most important item. In order to preserve the required degree of accuracy, a certain amount of maintenance is necessary, which consists of (a) Periodical Overhauling, (b) Periodical test. This period of overhaul and test depend upon (1) Type of meter (2) Cost of meter maintenance. (3) Revenue obtained by the undertaking from the sale of the water. These aforesaid three factors are variable, and the Water Authorities must ascertain the necessary information from the past experience, and the periodical tests. The quality of water is the most important factor for the life of the meter, for excessive wear, and secondly containing certain minerals, will set up corrosion and so on.

Say, the Municipality XYZ, has the below mentioned rule for charging for water consumed, whilst a meter is out of order or under repairs. In all cases, in which the Municipality XYZ, charges for water by meter measurement, it shall be a condition of such supply that the charges to be paid for water consumed, whilst a meter is out of order, or under repairs, shall at the discretion of the Chief Officer be based on any one of the following methods. (1) On the actual consumption recorded, if the meter is found to be registering, either not more than 5% fast or slow. (2) On the average of the immediately proceeding and next succeeding reliable reading. (3) On the reading for the corresponding periods of the previous year. (4) On the most reliable data obtainable. But the objection for the quoted rule 1, of the Municipality XYZ on the following grounds:—

(1) The criterion mentioned in clause 1 of the rule is unfair, both to the Municipality, and the consumers. (2) It is unjust to overcharge the consumer, if the meter is found to be running 5 per cent. fast, and if the meter is running 5 per cent. slow, the Municipality will clearly be losing its dues and ought to be entitled to bill for them. (3) If it were possible to ascertain without test that the inaccuracy varied between 5 per cent. above or below the standard, the clause might have had some justification. It is impossible to show without a test that the inaccuracy varies between these limits. If a test is taken, then the charge can only be on the conclusions to be drawn from the test, whether they be in favour of the consumer (very rarely) or of the Municipality. In authors' opinion, it is not possible to ascertain exactly the inaccuracy in the measurement of water supplied through the meter, by any other way, but by testing the meter. Besides, by taking the test at a subsequent date, it is even presumptive to suppose that the consumption recorded by a tested meter was necessarily the actual consumption for a back period, during which water was supplied through an out-of-order meter. To meet this contingency, it is but desirable to adopt some "give and take" policy by laying down a reasonable maximum above or minimum below, a definite standard. For example, in a meter for the measurement of the total water supplied to a large town, the correct registration of even so large a flow as 10 gallons per minute, is immaterial, whereas a Waste Detection Meter should register the total quantity passed by a flow of 0.1 gallon per minute over a period of even 10 minutes.

Overhauling of Meters:—(1) The profits of a water Company, selling water by measurement by means of meters, depends very largely on the condition of the meters, (2) It should not be allowed to stand on the connections for over 3 years, (3) Periodical renewal for test, overhauling consists of cleaning,

oiling and in some cases of the replacement of some of the running parts. After having been overhauled and tested, the meters are again ready for service.

The meter prices are as under:—

Size of Meter		Positive		Semi Positive		Inferential
½" ..	Rs.	90 ..	Rs.	30 to 90 ..	Rs.	25 to 60
¾" ..	„	120 ..	„	60 to 100 ..	„	50
1½" ..	„	280 ..	„	175 to 340 ..	„	120
1" ..	„	180 ..	„	80 to 150 ..	„	70
2" ..	„	380 ..	„	200 to 460 ..	„	200
3" ..	„	800 ..	„	500 ..	„	400
4" ..	„	1,300 ..		.. ..	„	500
6" ..	„	2,300 ..		.. ..	„	650
8" ..		..		.. ..	„	1,000
10" ..		..		.. ..	„	1,150

Prepayment Meters:—Any meter can be made to operate on the prepayment principle by adding to it a mechanism (as in case of electric Meters) which closes a switch in the main circuit when a coin is inserted, and opens the circuit automatically, when the amount of energy corresponding to the prepayment has been consumed. The Trip gear is actuated from the recording train, and a further payment is required to restore supply after interruption.

Legal:—The following case of a water Meter Registration is very important, as being the first of its kind brought before a Court of Justice, proceedings were taken under section 136 of the Public Health Act 1936. The Mere and Tisbury Rural District Council summoned Mr. Albert Hayter, baker of Hindon, and heard at the Tisbury, Wilts, Petty Sessions, December 1941, for payment of £19-0-6d, arrears of water charges. Mr. Hayter, in turn, issued a cross summons asking the bench to certify the quantity of water he had used during the period. Mr. J. J. McIntyre, Secretary of the rural District Council Association, appeared for the prosecution, and Mr. Hayter was represented by Mr. W. Harley Rutter.

The prosecution alleged that the meter reading for the period was 125,00 gallons, which was 100,000 gallons more than in the preceding periods. In the following half year, the reading returned to normal and whilst the suppliers claimed that there must have been excessive use of water, or that it was wasted. Mr. Hayter contended that the meter was at fault, and had probably jumped one figure adding 100,000 gallons to the amount consumed. Mr. J. Noel Wood, M.I.C.E., Engineer to the Halifax County Borough Council, said that he tested the meter, which was removed from Mr. Hayter's premises, and found it correct to within 1%. At slow flow, the meter was in favour of the consumer, "Meters like human beings," he said, "as they get older go slower."

Mr. C. Clemesha Smith, M. I. C. E., the Director of the Leeds Meter Co. Ltd., giving evidence for the Council said, that he had never known an occasion where a meter had gone wrong, and again righted itself. The meter which was at Mr. Hayter's was mechanically correct, and it was impossible for it to have slipped, and registered 100,000 gallons of water, which was not supplied. Witness handed in the blue prints of tests made on a punctured pipe at a pressure of 28lbs/sq. in. This showed that a puncture of 1/32" diameter passed 7.8 gals. per hour, 187 gallons in 24 hours and 1310 gallons in 7 days and at 3/64" the flow was half as much again as 3/32," it was 50 galls./hour; 1200 galls. in 24 hrs., and 72,000 galls. in 7 days. Other blue prints showed that the tests by the Leeds Meter Co., and Mr. Wood, produced practically identical results. He demonstrated his evidence with meters, which had been specially prepared for the use of the Court. Mr. McIntyre invited the bench to say that he had established a case that the reading of the meter was a prima facie evidence of the amount of the water consumed. The Chairman said it was fortunate that a bench was not often called upon to decide such cases. The

members of the bench were of opinion that the Rural District Council were entitled to payment for the water consumed and had decided accordingly. When Mr. McIntyre applied for the usual Costs, the Chairman said that the bench had decided not to allow them.

Metering and Charges at Bhopal

There are 350 stand posts in the city and 240 connections for Government offices, places of worship and other places of public utility which are free of all charges. House connections are 1,600 and these are charged as follows:—

1st tap $\frac{1}{2}$"	Rs. 1
„ „ $\frac{3}{4}$"	Rs. 2
„ „ 1"	Rs. 5
Subsequent taps $\frac{1}{2}$"	As. 8

Metering is only necessary where the water is not used for household purposes and hence all factories and garden areas are supplied by meters at the rate of As. 8 per thousand gallons.

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CHAPTER VI.

"AIR ESCAPES"

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Perhaps, the most important of the questions is that of Air Escapes in the Engineering Science and in the Engineering World.

The pressure of full air in the sewers, drains, water mains, &c., or in a process of charging a water main, for instance, is very well known to be the main cause of serious troubles, which include, delay in filling the mains, throttling and reduction in discharging capacity, risk of water hammering; and the increased tendencies towards corrosion of the inner pipe surfaces.

The water main flowing full off water cannot be emptied fully all of a sudden, unless water is replaced by the air, and hence the means of ventilation of some sort are absolutely necessary. The main objects of ventilation are as under:—

(1) To prevent air accumulating in the mains, and (2) to divert or drive out any air that may accumulate in the pipes.

Of these, the first is undoubtedly the most important, since if the ventilation is so deficient as to allow of the air within say "Sewers" becoming under pressure, a serious nuisance will almost inevitably result through the forcing of intercepting traps and disconnecting gullies. Moreover, while in extreme cases where a quantity of air has become so confined as to form an air lock and air pressure causing the floodings of cellars and basements through the backing up of the sewage (the word sewage means the organic matter, principally consists of human excreta and water) into them, thereby endangering the public health. The paper on this important subject was read by Mr. R. Reid, on "Ventilation of Sewers and Drains" before the

Institution of Municipal and County Engineers of London (the proceedings of the Institution of Municipal and County Engineers, London, Vol. 25), and is worth a glance. The theory discussed in this paper of the arrangement is that air enters at the low level and passes out at the tops of the ventilating columns. It has been proved, however, that though this theory is in general correct, under certain conditions the flow of air may be in the opposite direction, as for instance, when the flow of sewage is rising in the sewers, and consequently displacing the air contained in them.

The drains, Sewers, Water Mains, etc., generally designed to be ideal from the point of view of evacuation of air, and to have an uniform gradient, and would have no obstructions at any point on the system. Say, in case of supply mains from the sources of water supply, and the pumping mains that run a long distance with no outlets or junctions off them require to be well provisioned with the air escapes. As a rule, all high places on the larger (Mains, especially, if these places come near the hydraulic grade line, air vessel is provided with a view to allow the air to escape. If some means is not provided for the escape of air the result will be that the pipes may become air locked, i.e., volume and pressure of the air may reach such proportions as to diminish materially the area of the pipe available for water, and so reduce the discharging power of the pipe in case of water Mains. Few pumping Mains of any length, and no gravity trunk mains can have the ideal contour. Water mains, generally in practice follows the contour of the country along its route, and although it may pass through tunnels where in some cases, mountains are encountered. Where a trunk Main rises over any eminence, however, slight air is liable to accumulate, and to interfere seriously with the flow of water. It is customary, especially on long lengths of mains or pipes, where such eminences

occur, to fix an air valve, and be of an approved self-acting type. In connection with this, there should be an air pipe of about ¾" to 1" diameter with a full way-cock on same to be worked by hand to assist in letting large quantities of air off when a main is being charged after emptying. The leading mains, as per standard practice, to the distributing systems should also be furnished with self-acting air escapes, and with the air pipes to be worked by hand. The eminent Water Engineers M/s. J. A. MacPherson, M. I. C. E., (Chief Engineer, Bristol Water Works) and E. Shernan Gould, M. I. C. E., (in his paper on "The Elements of Water Supply Engineering in New York") considers that the air escapes are practically unnecessary upon the distributing mains in the sub-districts, their experiences being that there is no difficulty in this direction, the supplies off the distributing pipes acting as ample provision for the escape of air.

The function of the air pipe is to supply the air, and also to release the air. But, the air pipe is not necessary in large storage tanks, but it is necessary in the domestic storage tanks in India, the end of the air pipes, are generally protected with a mosquito-proof lid, as to prevent getting in of the mosquitoes, while in England, the end of the air pipes kept open. Air pipe is necessary always just near the stop cocks and it is not necessary, where there is a good fall or gradient given to the supply pipe, because the air will pass off or escape in the form of air bubbles out of the water stored in the storage tank.

The presence of the air in the pipes, what is commonly known as "milky water," is due to the air becoming charged with water during the re-charging of a water main which has been shut off for repairs or other departmental purposes. This soon disappears, and is, of course, quite harmless.

At all depressions of the mains, and at all dead ends, blow-off or wash-outs or scour valves, are necessary, for draining the leading mains. They

are special valves that are opened occasionally to remove silt and sediment by allowing the water to run out, until the water runs clear. Hydrants are often used for the same purposes as blowoffs.

There are 3 types of self-acting air valves, namely:

(1) *Self-acting Single Air Valves*:—With a floating gutta percha ball, to act under pressure, and allow the small quantities of air, which occasionally accumulate on the summits of the pipe lines.

(2) *Self-acting, Double Air Valves*:—The ball on the right acts under pressure, allowing the small quantities of air that accumulate to escape through the small hole or orifice, the same as the self-acting single air valve. The large aperture on the left is intended for the escape of the large quantities of air, while the pipes are being filled wtih water, the floating ball closing same, when the main is fully charged with water.

All air valves are generally of double ball type with the full way orifices to allow the rapid passage of air, when pipes are charged or empty. The sluice valves are placed under each air valve in practice, so that the latter can be isolated from the main if required.

(3) *The Triple Ball Air Escapes*:—The centre ball acting under pressure, and allowing the small quantities of air that accumulate to escape, while the two large apertures, one on each side of the centre one, are for the escape of large volumes of air from the mains.

All air valves are on the same principle, and the air valves should be correctly designed for the pressure on the main.

Most of the air valves are 8" diameter (of the Bombay Water Supply) fixed on branches, which are hydraulically passed from the flat plate in halves, the two pieces being butt jointed and accetylene welded.

The free air is introduced in the water main in various ways:—The original air may be trapped at peaks, or by obstruction, i.e., partly closed sluice valves, and the leaks in the suction pipes will have also the same effect. The free air from vessels or from the air pockets formed by the heads of the sluice valves may expand and escape into the pipes under a fall of pressure. Effusion of air from water itself also occurs, particularly with the changes of pressure and temperature. Water can absorb more air at high pressures than at the low pressures, and when the pressure is reduced free air may be given off. The rise in the temperature also tends to reduce the amount of air that water can hold in solution, and free air will appear in the pipe line from these causes.

Location of Pipe Lines:—The avoidance of air troubles, is as far as possible by the favourable location of the pipes, and there are number of factors, which affect the operation of the pipe line.

(1) Standard type of air valves equipment may be used.

(2) To lay the pipes always well below the hydraulic gradient, and not less than 20 or 30 ft. below the hydraulic gradient, should ever be aimed at.

(3) Horizontal long lengths of main should be avoided wherever possible.

(4) Grades to be made greater than 1 in 500.

(5) Low velocity as 8" or 9" per second should be avoided, on ground that the air bubbles generally rise vertically in water, having such low velocity.

(6) Use of specially sensitive devices, which need careful maintenance, be avoided.

(7) Flow conditions, during scouring operations should be considered, and to consider the change of hydraulic gradient, when scour valves are opened.

The cases are on record in U. S. A. Water Works, where air valves which are fitted at the heads of the hydraulic gradients have had to be renewed, in order to permit of adequate flow for the scouring, as per

the remarks of the American Water Engineer, Mr. MacGregor, M.A.S.C.E.

The next important factor to be considered is the location of the air valves. First and foremost, air valves are provided at all the peaks, and the peaks are not judged solely with respect to a horizontal datum, but with respect also to the maximum hydraulic gradient. The reason being that the hydraulic gradient is the virtual free water level along the pipe line. It varies with the changes of pipe diameter; pipe surfaces and variations of velocity caused by the branch mains, and the local joints of draw off. The standard English and American practice, in respect of placing of the air valves on long water mains, while ascending or descending is at ¼ or ½ miles intervals.

The following are the typical illustrations on this subject matter (see page 167):

Figure 16:—shows a section of a pipe line running parallel to the hydraulic gradient and constituting the peak.

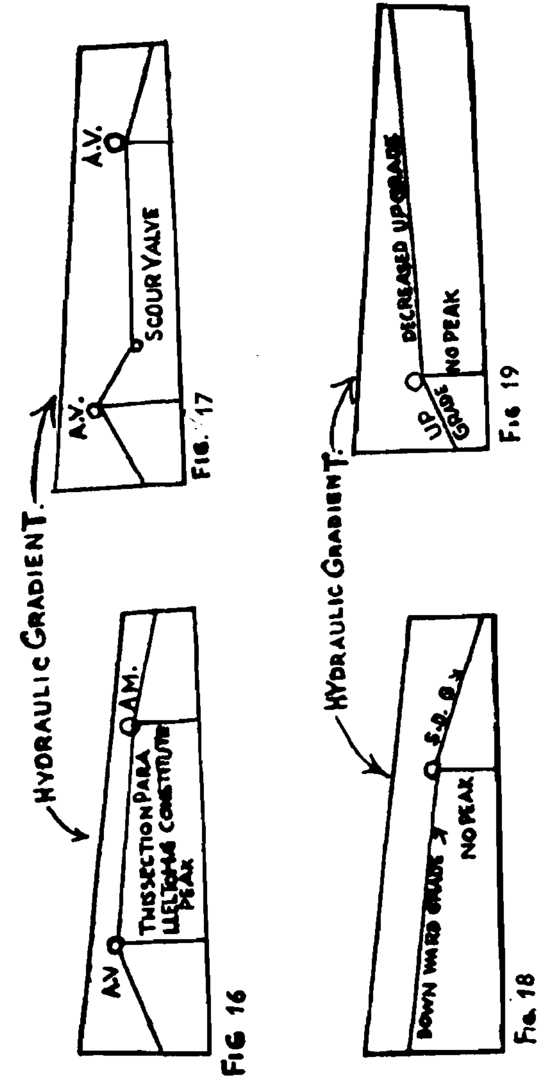
Figure 17:—shows a section of a pipe line having downward grade and point of increase of downward grade.

Figure 18:—shows a section of a pipe line forming a peak with respect to horizontal also to the hydraulic gradient and peak with respect to the hydraulic gradient only.

Figure 19:—shows a section of a pipe line having upward grade and point of decrease of upward grade.

If the water main goes well above the hydraulic gradient, i.e. say over 20 ft. then pumping is resorted to. This is also a typical case to remember.

In conclusion, this subject of air escape is very important to Engineers, Doctors, Scientists, etc.



A.V. means Air Valve,
I.D.G. = Increased Down ward Grade.

Fig: 16 to 19.

CHAPTER VII.

"MODERN METHODS OF WATER FILTRATION AND PURIFICATION."

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"MODERN METHODS OF WATER FILTRATION AND PURIFICATION"

Water filtration and purification have been the outcome on the part of public authorities to provide a regulated and wholesome supply of potable water to the increasing population in Modern Cities and Towns. With the springing up of Industrial Towns, a regulated water supply has been found absolutely essential.

Though every precaution should be taken to secure a really good water for the supply of a town, it seldom happens that this object can be attained in its entirety. Almost always a choice has to be made between the stream water of a soft character, and perhaps slightly tinged with peat, and liable to be rendered useless during floods by the amount of mud in suspension, and a clear Spring Water, pure in other respects, but possessing a high degree of hardness. This choice of evils is often forced upon the authorities of small towns and villages, where means prohibit their bringing in water from a distance. They are consequently compelled to select water near at hand, even though it be objectionable in some particulars.

The impurity of water as it generally termed, is caused by the presence in it of "Matter," either in solid or in Gaseous State. The Solid matters may be either Organic or Inorganic, whilst the gases in water, are generally derived from the combination of the Solids with each other, or with water. Solid Matters are found in water in two conditions:—

(1) In a state of Mechanical mixture or Suspension.

(2) In a state of Chemical Combination or Solution as it is technically termed.

The muddy water is an example of the first state, because on the water being filtered or allowed to settle, the solid matter will take the form of Sediment, and the water will become clean. The Sea-water is an example of the second state, because neither filtration nor settlement will remove its contained Salts. It will thus be seen from this, that it is a matter of great importance to know the form in which water is polluted, whether mechanically or chemically.

The Purification of water mechanically polluted is extremely easy, and only requires time; whilst on the other hand, the removal of impurities Chemically Combined with the matter is in most cases very difficult, and in fact impracticable, when the water is intended for the Public Supply. As a rule, water found chemically impure to a serious extent must be rejected. The presence in water of the different matters produces different effects. One of the important results, due to the presence of certain foreign matters in water, is known as Hardness. The water permanently hard should be rejected for the supply of a Town. The majority of Water Authorities are in favour of soft water for domestic and other uses, though some eminent men still hold strongly to the hard water. It is stated, in a paper read by Dr. Macadam before the Social Science Congress in London, in 1868 and 1888, in support of the latter view that in most of the large towns, where soft water is used, the death rate is higher than in those places, which are supplied with hard water. It is also stated that where the conscription for the Army is in force, more conscripts are rejected in those places or districts, where soft water is used by the inhabitants than where hard water abound, the ground of rejection being want of proper physical development. The hard waters are generally speaking much more palatable than those of the softer quality. To a person accustomed to the former, the contract is extremely great, for

the soft water is certainly very flat and tasteless. The only strong argument advanced is the great saving of Soap where its use ensures. Nothing can be more annoying to the washer-woman than hard water.

Many processes exists to remove the impurities found in water, but most of them are impracticable, on the ground of expenses. Anything that can be attempted in this direction must be simple and inexpensive, and the only process successful and economical has been filtration. This process, generally speaking, removes only Mechanical impurities, and it consists simply of a method of passing the water through some filtering medium, sufficiently close to intercept the small particles of impurities, but open enough to allow the free passage to the water. A certain amount of purification can be produced by settlement, where a sufficient time is allowed, and a large amount of the mechanical impurities may be got rid of. The usual way, in works of any extent, is to pass the water through a filter bed, after it has had the certain time for settling. The filter is composed of several layers of materials, the layers being disposed one above the other, the lowest one being the coarsest, and the upper one, the finest. The water is admitted on the upper layer, whence it passes downwards, and then into the main pipe for distribution. The greater part of the actual work is done by the upper layer, and the lower layers merely serve as a previous support to the upper layer. These layers are generally composed and arranged as follows:—Bottom layers (generally of broken tiles, stone or brick) 2'—0" thick, the next of coarse gravel 2'—0" thick, the next of fine gravel 1'—0" thick, the next of coarse sand 1'—6" thick, and the uppermost layer of fine sand, 2'—0" thick as per Fig. 20.

— SECTION OF A SLOW SAND FILTER —

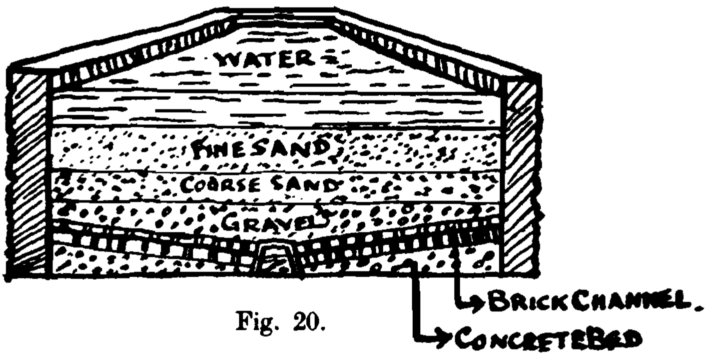

Fig. 20.

This arrangement may, however, be modified to suit local circumstances, as it is always best to form the filters of materials found close at hand. The quantity also known, it would be mere a matter of calculaton to fix the surface of filter wanted. It has been found, in general practice, that 1 square yard of filter area will pass from 500—1,000 gallons of water in 24 hours, or say, for a rough average about 750 gallons. Hence for a town getting a supply of say, 29,000 gallons per day, the filter bed would require a surface of 27 square yards. In some cases, the duplicate filters are provided, so that one can be used at a time, and the other cleaned. The sand filter has held its place, as the best, on account of its cheapness in first construction, and what is of nearly as much importance, "its Self-Acting Character, and non-liability to go out of order." Sand filters are largely used at a lower rate than mechanical filters, and cleaning is done by removing by scraping of a surface layer of dirty sand, (as in American Practice), instead of by washing the whole sand layer by a reverse current, (as in the English Practice).

The water should be well aerated, a deficiency of Oxygen making it more difficult to free it from Organic impurities. The Aeration also facilitates the precipitation of any iron there which may be in solution. Aeration is generally obtained by exposing water in an open channel, letting it fall down a series of steps, discharging it as a fountain into an open reservoir which is the best method, as in case of Tata Hydro Receiving Station at Dharavi, or any other similar means. The cheapest, simplest and most generally applicable method of removing tastes and odours is by Aeration.

.Modern Mechanical Filtrations to remove Tastes and Odours

Water, which is subjected to a very bad tastes and odours, is successfuly purified by a process of which, Mechanical Filtration is one step. The whole process consists of the following:—

(1) Use of $CuSO_4$ in the reservoir to hold down the growths of Organisms.
(2) Aeration of the water.
(3) Coagulation followed by passage through a basin, holding 2 or 3 days' supply.
(4) Aeration of water on leaving the basin.
(5) Mechanical filtration.
(6) Aeration on leaving the filters.

Water Purification System:—Standard Practice for Town Water Supply is to use Rapid Sand—Filtration plant, in which the water is caused to pass by gravity through a deep layer of graded sand and pebbles, carried on a perforated floor in large open concrete tanks, generally rectangular in shape. This type of filtration is known as Gravity Filtration Plant.

The processes of Water Purification, finding practical application for Municipal purposes are (1) Coagulation and Sedimentation, (2) Slow Sand Filtration, (3) Rapid Sand or Mechanical Filtration. The latter has proven to be more efficient and economical.

The second process is of English origin, and dates from about 1830. In America, it has found extended use in the older installations, although of recent years, the mechanical process has become an important competitor in plants of large sizes.

Rapid Mechanical Filters: *"The Paterson's Filters of Gravity type"* consists of Coagulation tank, the necessary chemical solution tanks, measuring gear; dosage plant, chlorination plant, and air compressor plant for air agitation of the sand of the filter unit for the purposes of clearing the filtering medium. The necessary scour and drainage arrangements have to be made.

Paterson type of Rapid Gravity Filters, comprising, inlet; one main rectangular penstock with gun metal faces; level gearing, extended spindle and hand wheel, and the hand wheel, being placed in a suitable position near the Fluxograph for effecting the necessary control.

Reagent Preparing and Proportioning Gear:—Patent Paterson weir type automatic measuring and chemical supply gear, the main tank being fitted with suitable baffles to quicken the water, before flowing over the rectangular measuring weir. This weir is in the form of a heavy brass plate with knife edges, mounted on a cast iron frame. A float (heavy) controls the positions of the taper valves, which regulate the discharge of chemicals in precise ratio to the flow of water. The taper valve and seating are mounted in a receiving tank for the reagent solution, the level of this tank being kept constant (practically known as constant level tank) by a ball valve with copper float and lever fitted with adjustable quadrant, all constructed in acid resisting material. This ball valve would be piped to the reagent storage tanks.

Fluxograph:—Fluxograph, for continuously recording and indicating the rate of flow, giving a daily chart of the quantity of water treated.

Reagent dissolving and Storage Tanks:—Comprising the filling up piping, the acid resisting draw off pipes, and valves; and air agitating piping. Each tank is fitted with solution level indicator, so that the depth of the reagent may be readily seen.

Mixing and Aeration Trough:—It is constructed as part of the coagulation and sedimentation tanks in masonry always for mixing H_2O with the reagent, and discharging same into the receiving channel.

Coagulation and Sedimentation Tanks:—To be of masonry and fitted with distributing and collecting channels for feeding the filter inlets and constructed to facilitate the movements of sludge, when clearing out. The latest practice favours continuous flow, sedimentation, and the permissible velocity is from 2 to 5 inches per minute.

Rapid Gravity Filters:—Each 22' by 18', filling a total filtering area of 2,376 sq. ft., capable of furnishing the output of 4.5 million gallons, when filtering at a speed of 77 gallons per sq. ft. per hour. All the necessary mechanical equipment, including inlet valves and operating gears, wash water, air, waste and bye-pass valves, Paterson patent manifold strainer pipe system, consisting of galvanised wrought iron laterals; provided with gun metal orifices, and connected to heavy cast iron headers by means of special cast iron tees; separate air manifold pipe system, inspection box fittings, including Paterson Patent automatic controllers with weir plates, control valves, floats, levers, spindles, links, ball bearings, flow discharge gauges.

Filtering Medium:—Sand, in each filter units consists of depth of 30" of river quartz sand, properly washed and screened to secure the effective coefficient, and beneath the sand is a supporting stratum of graded and screened layers of gravel to a total depth of approximately 15". Above the strainer system is laid a layer of very coarse

screened gravel. Above this coarse, gravels are laid, the successive layers of screened gravel, the finest being at the top supporting the sand.

Air Compressing Plant, Receivers etc.:—Compressors are generally driven by a separate electric motor, and capable of delivering approximately 60 cu. ft. of free air per minute, against a working pressure of 75 lbs. per sq. in.

Each compressor would be capable of performing the duty, while the other compressor set acts as a stand-by. The maximum power for either compressor is 9 Brake Horse Power for average period of 4 hours per day. Storage receivers for compressed air, each 4′—9″ diameter by 18′ long constructed throughout of 5|16″ mild steel plates, all hydraulically rivetted, and suitable for a working pressure of 75 lbs. per. sq. inch.

Paterson Chloromome:—Manometer type "Chlorommone" described in the Book, "Water Sterilisation by Gaseous Chlorine." With the chlorinating plant would be supplied one Paterson Ortho-Towdine testing set for determining the amount of free chlorine in the treated water.

Testing and Inspection:—Generally, pipes and all other castings are hydraulically tested to at least ½ times the pressure, they will be subject to, when in operations. The rate of filtration varies from 2,000,000 to 6,000,000 gallons per acre of filter surface per day, and 3,000,000 gallons being very commonly used, or from 3 to 5 vertical inches per hour are seldom used. The degree of purity of water attained by Paterson's Filtration process is the highest.

Within the last few years another type of mechanical filter has been introduced, viz., the Ransome Rapid Filter used largely in America.

The Theory of Filtration

Filtration is a combination of several processes. The most obvious of these, is the straining out of particles too large to pass the interstices between the Sand grains. In order to stop the other smaller particles of suspended matter passing, the sedimentation tanks are used.

Essentials in Rapid Sand Filter Washing

Whether low velocity (i.e. 1½ ft. to 2 ft. per second) washing coupled with air or Mechanical agitation of the sand layer, or the application of wash water alone at high velocities (i.e. 2 ft. to 6 ft. per second) is the better method, need not be discussed here. Perhaps in some localities one may be better than the other. There are certain essentials in rapid sand filter cleaning, however, which do not allow of argument. These are, that, whatever the procedure followed, the gravel layer must not be unseated, and mixed with the sand, the filter bed proper must be floated, and so broken up as to be amenable to thorough and economical washing; the upward flow of wash water must not be so great as to carry away with it appreciable quantities of the filter sand, and finally, but by no means least the foreign matters thus separated from the sand must be carried upward, and out of the filter tank with the wash water.

Filter Cleaning Standard Practice

Violent air or Mechanical agitation prior to the application of the wash water tends to thoroughly break up clogged section of the bed, and to comminute the particles of foreign matter separated from the sand. Thus, the specific gravity of such matters is lessened, and their floatation by the rising wash water which follows made easier. Application of wash water alone at high velocity may not break up these lumps of foreign matter into such fine particles, but the more rapidly rising column of water is expected to counteract this feature through its ability to float particles of relatively high specific gravity.

The Bacterial action plays a most important role. After a filter is in operation for a long time, a slimy gelatinous film forms on the surface, and on examination will show this jelly to be of bacterial Origin. The surface coating has been named the Schmutzdecke (i.e. dirt cover) by the Germans, who attribute most of the efficacy of the filter to its action and place, so much confidence in it, that they consider a sand bed 1 ft. thick sufficient, if properly coated, to yield a satisfactory effluent. The efficiency of the filter increases, with age, due to continued bacterial growth, and the resulting formation of slime and jelly in the interior. This jelly is capable of absorbing the colour from the raw water upto 25%. There is also a small amount of chemical action, within the filter, in the way of Oxidation of the dissolved organic matter, contained in the water. For large towns, where filtration is necessary, the downward system, where the water by its own gravity is made to pass through layers of sand and gravel is generally adopted.

Water Contains Bacteria

That ordinary water in its raw state is not suited to human consumption is shown by the Bacteriologists, like Pasteur, Koch and other noted investigators. It has been shown that impure water is an agent in the transmission of disease. The potable water, as a rule, should be clear, agreeable and refreshing. A prolific source of complaint due to Algae and plant life is bad taste and odour. River and natural spring water contains Salts of lime and Magnesia, which impart hardness to the water. Finally, the most important of all is that the water especially in the city supplies should be free from the bacteria of disease, like B. Coli, due to Sewage Contamination. It is therefore axiomatic that the general health of the City very much depends upon the purity of the water supply.

The Methods of Water Purification

The subject of Water Purification concerns the Chemist and the Engineer. The slow sand filtration has been found to be still suited for small towns, where labour is cheap, and where the water is free from chemical impurities and bacteriological contamination. But the modern filtration which effectively makes the water pure depends on the use of chemical agents, in the course of filtration.

The Paterson's, the Jewell's (Jewell's Pressure Type Filters are in use at Nasik Distillery), the Bell's Filters and the United Water Softness are few of the water filtration and Purification plants well-known in India. Let us take the example of the installation of Water Softening Plant of the United Water Purification Co. of U. S. A., known as "Multi Film Washers" at the Gas Co. of Bombay. There is a well, with a 3" suction pipe to the weir pumps. The pumped well water is then made to pass through the Water Softening Plant. The well water, after being softened by this arrangement, is used for boilers, cooling tubes, etc. This plant was installed by the Company in the year 1927. This is an economical arrangement, in which the used water can be utilised safely for the certain works, over and over again, such as cooling tubes, etc. The Water Softening Plants are installed, on a large scale on B. B. & C. I. Rly. (at Ahmedabad, etc.), G.I.P. and on the other Indian Railways.

Filtration

The publication of Paterson Engineering Co. (India) Limited, which is entitled to "Modern Water Treatment Plaint" is a very interesting general description of water purification in the light of modern scientific research. This Co. has specialised in the purification of water supplies for municipal and industrial requirements, and its installations are effecting satisfactory treatment of water from the most unpromising sources. This

Company has carried out research regarding the peculiar nature of tropical water supplies, and the accumulated information is available for application and guidance in the development of new water purification projects. It is learnt from this Company that the total capacity of their water treatment plants installed in this country is about 600 million gallons per day, among the more important installations being Imperial Delhi, Simla, Jaipur, Lucknow, Jamshedpur, Hyderabad (Dn.), Poona, Jammu, Trivandrum, Erode, Kalyan, Bhusawal, Rajahmundry City, Madras, etc.

The Object of Purification

The object of purification is to remove from the water any traces of pollution that may give rise to disease, and also to remove suspended matter, when the water is turbid, and to dissolve mineral matter to render water soft. The principal methods employed for the Water Purification on a large scale are, Storage, Filtration and Chemicals, but no method of purification can be considered satisfactory from a sanitary point of view, that does not eliminate the germs of water borne diseases.

Deterioration takes places principally in warm weather. It results from the growth of microscopic organisms in the water. The mineral food supply is always contained in the water and in the air. The organisms decompose, carbonic acid always present in both air and water, and with the aid of light, build up from the carbon obtained from it, the organic matters of which they are composed, precisely as the wheat plant builds up its structure from inert mineral matters. The advantage of storing filtered water in the dark, is that it will keep entirely without deterioration. As a rule, all reservoirs built for filtered water have been covered, and the top is well grassed over, and used as a park.

Pressure Filters:—Pressure filters may be located between the pumps, taking the water from the

source of supply, and the filtered water storage reservoir, (operated under a pressure of 40 to 60 lbs. per sq. inch). They are, however, neither efficient nor reliable from the sanitary standpoint, and are also not economical to operate.

Fluctuations in Consumptions:—Consumption is greater in hot summer weather, and in some countries in severely cold weather (waste). For a few days, consumption may rise 50% above the mean, and for any one whole month it may rise the average consumption to 10-20% above (Burton). The maximum hourly demand may be from 2 to 3 times the average hourly demand. Three quarters of the whole supply is generally used, between 8 a.m. and 8 p.m. From 9 p.m. to 6 a.m. the draught averages 1½% per hour of the total daily draught, increasing from 4% at 6 a.m. to 8% at noon, decreasing slightly till 2 p.m., and rising again to 8% at 4 p.m.; gradual decline to 3% at 9 p.m. (Experiments made by Mr. Marten at Wolverhampton, ('The Constant Supply').

Slow Sand Filtration

Slow Sand filtration is known as the English System, and it was introduced first in England in 1830. These filters consist of large shallow reservoirs containing sand and gravel as the filtering media, and the water is passed through them slowly from above downwards. This process is called slow filtration in contra-distinction to rapid filtration.

The typical section of a sand filter is shown in Fig. 20. The action of slow sand filters is threefold, namely, Physical, Chemical and Biological. The slow sand filter beds of Calcutta Water Works at Pulta, covers 700 acres, and supplies 60,000,000 gallons of filtered water to the city daily. The Sedimentation tank in use at Calcutta Water Works is of the Continuous Settlement type, and not of fill and draw type. The example of fill and draw method or discontinuous method is at Serampore, where the water for Howrah is filtered. Authors are grateful to

the late Calcutta Water Works Engineer, Mr. Ghorkoddo, for showing and explaining us all the works in 1934.

Mechanical Filters

There are 2 general classes into which Rapid Sand filters may be divided.

(1) Pressure Filters.

(2) Gravity Filters.

The pressure filters are generally located between the pumps taking the water from the source of supply, and the filtered water storage reservoir, operated generally under a pressure of 40—60 lbs. They are however, neither efficient nor reliable from a Sanitary stand-point, and are not economical to operate.

The advantages claimed for Rapid Filters are:—

(1) Small area of land is required.

(2) No Settlement tanks are necessary.

(3) Filtration is continuous.

(4) Filtering material does not require changing and is thoroughly cleaned in a few minutes.

The Jewell filter used at Nasik Distillery is the pressure type filter, circular in section, and is made of steel. It is entirely enclosed, so that it can be placed directly on the pumping main. The filtration head must not exceed the maximum allowed in a gravity type of filter. These filters are very convenient for commercial installation, where they have to clean turbid water, and make it fit for all uses. This type of filter requires to be cleaned more frequently.

For large towns, where filtration is necessary, the downward system, where the water by its own gravity is made to pass through the layers of sand and gravel, is generally adopted, in practice. Sir Alexander R. Binnie, the eminent Water Engineer, in his book, "Rainfall Reservoirs and

Water Supply," recommends that the whole process of the filtration depends largely upon the slowness with which the water passes through the filtering material, and in such a downward system of filter, for very efficient work, this should not be greater than 4" vertically per hour, or about 2,178,000 gallons per acre per day, consequently about 2,200 square yards of filtering area should be provided for every million gallons required per day, but provision must be made for more area (10—25%) to allow of cleaning, repairs, etc.

Within the last few years, another type of mechanical filter has been introduced, namely, the Ransome Rapid Filter, and used largely in America.

Rate of Filtration:—Filters give more than 15,00,000 gallons a day upto about 3,000,000 gallons per acre of filter area a day. Whereas rapid filters give something like 100,000,000 gallons a day per acre of filter area. The rate, therefore, works out to 30 to 200 gallons per sq. ft. area per day for slow filters and to about 1,500 to 2,500 gallons per day in the rapid filter.

Rapid Filtration

It is a combination of Chemical and Mechanical treatment. The introduction of Sulphate of Alumina or Alum, which is an amphoteric salt capable of decomposing in a slightly alkaline media, has the power of coagulating the gelatinous coagulum aggregates, and when subsiding it drags down all suspended matter and colour. The exact quantity of Chemical to be added is controlled by the delivery of water through a weir to the settling tanks. As the depth of notch over the weir could be made a direct indication of the precise quantity of water going to the settling tanks, the varying depth is made use of by suitable mechanical and hydraulic contrivances to allow the correct quantity of the Chemical to mix with the water in the settling tank. The elimination of iron in the Paterson Plant is effected by coagulation with lime.

The rate of filtration in the Slow Sand filters varies with the character of the water, but in England, a rate of 2 gallons per square foot per hour is adopted. The rate of filtration in Rapid Mechanical Filters is normally 80-100 gallons per square foot per hour. The general principle of action of Rapid filter is similar to that of the slow filter, the former cannot usually be relied upon to give complete bacteriological purification, as the latter, when properly supervised, so that the Rapid filter is most useful for waters, which are epidemiologically satisfactory before any treatment. Rapid filters, therefore, cannot always be relied upon to produce a bacteriologically satisfactory water. The real filtering medium of any filter is the Colloidal matter within the filter bed.

Construction of Rapid Filters

Most of the types these filters are the closed or open types, operating respectively under Gravity or Pressure. A Mechanical wash geaer is often introduced, and in some systems the filter bed is agitated by the compressed air.

From Osmansagar and Himayatsagar water is carried through the conduits to the filters at Asifnagar. The Asifnagar filters consists of 12 filters of Paterson Rapid Gravity type, and 5 Candy filters. These sets are capable of yielding 14 million gallons of pure chlorinated water supply per day.

Water Softening

Hard water is detrimental to steam users, and those using water for the trade purposes. The United Water Softeners Claim to be the exponents of water softening. Their system is known as the "Permutit or Zeolit Process." The Permutit is an artificial zeolite having greater capacity or readiness than the natural product.

Chlorination

The treatment of Municipal Water Supply by **Chlorination is a modern process, and was first used** at Lincoln by Mr. A. C. Houston to disinfect the water works system, which had become infected by typhoid organisms. Thereafter, and the use of chloride of lime for water purification, both by itself and in conjunction with the filtration became very popular in America. During the last World War of 1914, it was used by the Military Engineers on the advice of Dr. Nesfield of I. A. M. S. in 1913, with much success. The water supply of London, for example, was chlorinated, during the last World War, primarily as an emergency measure, but the successful and economical results obtained led to its adoption, as a routine process. Its use has then been extended to many towns in India, viz., Bombay, Simla, Calcutta, Delhi, etc. The initial cost of chlorination is cheaper by 1 to 5% of filtration plant *of equal capacity and efficiency, and it provides* positive protection against accidental infection.

The value of chlorine as an oxidising and sterilizing agent has long been recognised. The elimination of pathogenic bacteria in potable water is effected by means of suitable doses of chlorine, or various substances having chlorine as the base. The chlorine cylinder usually contains 70 lbs. of chlorine at 120 lbs. pressure, which will treat 28 million gallons of water. There are three typical types of appartus available for adding chlorine gas are:—

(1) *The Chloronome manufactured by the* Paterson Engineering Company, Limited.

(2) Wallace—Tiernan Gas Administrator, by the United Water Softeners, Ltd.

(3) The Candy Chlorine Gas Apparatus, by the Candy Filters Co., Ltd.

The fundamental principles are the same, and in all cases aim at introducing chlorine gas in a constant pre-determined proportion. The Authors now come

to the service chlorination or some other form of sterilisation, which is of prime importance, because there is definite line of defence of a very direct and positive nature against pollution. If sterilisation is used, and is efficiently controlled and maintained then the Engineer in charge of the Water Works or Supply can sleep happily at night. Trouble if there is any, nearly always arises through some failure in the application. The Authors suggest that the first and most effective safeguard is a continuous record of the dose given. Such a record shows at once, if there has been any failure, and the next best thing to having no failure is to know exactly when a failure occurs so that it may be traced to the source, and a similar experience guarded against in the future. It is therefore desirable for all chlorination installations to be provided with an automatic recorder, and the charts should be examined by the Engineer-in-Chief in Charge every week.

The liquid chlorine is also used on a large scale, as a substitute for Hypochlorite of lime. It is expensive, and less likelihood of producing tastes and odours. The Ozone, if used instead is free from these objections. It is too expensive for general use. Ozone has a powerful effect in the purification of water, and it is certain, as once said by Dr. Rideal (the well-known chemical authority) that Ozone will secure in the very near future, much wider application in the purification of water. The main object of adding chlorine to water is for the purpose of destroying any pathogenic organisms that may be present. It prevents and checks epidemics of water borne typhoid.

The use of chlorine for the sterilisation of water has now been in practical use for over 30 years, and the amount of chlorine required will vary according to the nature of the water being treated, but usually less than 1 part of chlorine per million parts of water

will ensure the complete destruction of pathogenic bacteria in water, and the palatable qualities of the supply are not affected. It is added to the water in the gaseous form readily obtainable from cylinders of liquid chlorine. There are several well-known makes of plant on the market, which have been specially designed to administer small doses of chlorine to water with the necessary degree of accuracy.

The chief points in the application of the chlorine are:—

(1) Provision of an adequate contact period after the addition of the chlorine, i.e., in many cases, complete stabilisation is effected within 30 minutes after the chlorine is added.

(2) Uniform administration so that each volume of water receives the required amount of chlorine.

(3) Accurate dosage is essential since under *dosing implies incomplete sterilisation* and overdosing may result in the water acquiring a taste of chlorine.

Ammonia chlorine treatment:—This treatment is useful where the raw water contains traces of impurities, which produces taste-forming substances on the addition of chlorine alone. The use of ammonia avoids the formation of such tastes, and sterilises the residual of free chlorine in the water.

Chlorination is also used for controlling the growth of mussels, which frequently occurs in pipe lines, where the supply is taken from tidal matters.

Break point chlorination:—This is the recent development of the chlorination process and the application of increasing doses of chlorine to water does not automatically produce an increasing content of residual chlorine. In fact, with some waters, particularly those pulluted with ammonia, there is a range of chlorine dosage, which decreases the residual chlorine until a minimum is reached. This minimum

is called the break-point, and beyond this point true chlorine residuals are obtained. The claims for break-point chlorination may be summarised, as complete sterilisation and complete avoidance of taste, and some improvement in colour and appearance. (For those interested please refer to the paper read by A. T. Palin, B.Sc., A.M.I.S.E., on "The break-point chlorination of water," before Institution of Sanitary Engineers in April, 1945.)

The Importance of Water Purification

Water Purification requires for its accomplishment, the application of carefully designed plant to suit the local conditions. The public authorities should therefore, design the proper one, as upon this depends the Health of the teeming millions. The Engineer sometimes seemed rather carried away by the glamour of constructing large and important works, and were perhaps apt to overlook the necessity for day to day care. Failure, however, generally resulted from inefficient management, and the failure of the human element. It was necessary for local authorities to make sure, that they appointed none, but efficient Officials, and paid them adequate salaries. We will give here the example which is very interesting. At Chester, the sewage works, adjoined a built-up area, on the other side of the river was one of the local Golf courses. Should any smell reach that Golf Course, the language of the golfer's was apt to become of a Sanguinary character. Not very long ago, it then became necessary to remodel and enlarge the sewage works, etc. Such schemes, as a rule, should be laid out in the first to look more pleasant, and the road along which the men come to pass be planted with terbaceous border, and make it a real flower garden. The whole aspect of the place should be more of a park, than of a Sewage or Water Works.

A Paterson chlorinating plant of Bombay Water Supply to deal with 90 million gallons per day has

been erected at Powai. Liquid Chlorine is used in cylinders, and the outfit generally is similar to those used by the Metropolitan Water Board. The Chlorine Solution is pumped direct into steel mains and to prevent the chlorine effecting the steel, the nozzles or diffusers of the chlorine delivery pipes discharge into 24" diameter, heavily enamelled iron tubes about 50' long, which are slung inside the 6ft. diameter main. These inner tubes are fitted with baffles to promote mixture.

The Examples of Modern Filtration Practices

A further stage in the development of the large Railway Colony at Asansol has taken place recently, with the installation of a modern water filtration plant. The installation was opened in the presence of a big and representative gathering, by Mr. A. C. Dunsdon, Deputy Chief Engineer of E.I. Railway. This plant has an hourly capacity of 40,000 gallons. The process of purification was demonstrated to those present, and all were thoroughly impressed by the manner in which an evil looking supply was converted, in a short space of time, into a clear, sparkling effuence, fulfilling the most stringent standards of Modern Hygiene.

The other example is of the Rapid Gravity Filtration Plant, at Jalna, in His Exhalted Highness The Nizam's State. The results are interesting as showing economy in operation costs, that can be obtained with the latest improvements in Rapid filtration practice. The scheme allows for supplying a population of 50,000 at the rate of 18 gallons per head per day. Water is obtained from the Ghanawadi Tank, and is brought to the Water Works through a gravitation main, consisting of 5 miles and 21 inches diameter Hume Pipe. The complete chemical filtration and sterlisation plant was supplied by M|s. Candy Filters (India) Ltd. of Bombay. The Building work was carried out departmentally by the Special Engineer, District Water Works, and

the plant was first brought into operation in February, 1933. The Raw Water is treated with a dose of Sulphate of Alumina, and is then delivered to settling tanks through a venturi flume, which controls the flow recorder, which also registers the quantity of water treated by the plant. Settled water is delivered to rapid gravity filters, which are fitted with the Company's Type "A" automatic controls, and differential loss of head gauges. The final sterilization of the filtered water is by means of a Candy Patent Chlorinator. The air and water required for scouring the filters are obtained from a Reavell Compressor, and a Worthington Simpson Centrifugal pump, both units being driven by belt from a horizontal Blackstone Crude Oil engine. The Normal output of this plant is 600,000 gallons per day, but provision has been made for increasing the number of filter units at a later date. The filter units are capable of sustaining an overload of approximately 50% without any reduction in the quantity of the effluent. The filter washing is done, when necessary, as indicated, by the loss of head gauges, and the quantity of wash water consumed for each wash is carefully measured and recorded. The wash water pump delivers the correct quantity of water direct to the filter, so that, by noting the lapse of time between opening of the wash water valve and final closing of the valve, an accurate estimate of the quantity consumed is obtained. As the wash water valve is partially closed at the beginning and end of the washing period, the recorded figures are on a conservative basis, but in computing the final wash water consumption figures, an allowance of 10% for possible errors in observation, and a further allowance of 1% for possible errors in the flow recorder readings has been made. The records show that during the worst period of the monsoon in the year, say 1933, the average wash water consumption, subject to the corrections already mentioned, was 0.4% of the total water filtered, although the maximum

turbidity recorded during the period in question, was greater than 150 on the A.P.H.A. standard. The average wash water consumption 0.28%, including the monsoon period. The result of this plant compares very favourably with the record wash water consumption figure of 0.23% obtained on the Candy Filter Plant installed at Wakefield in England, for which the company received a bonus of £800. The Jalna Plant was installed under a guarantee that the wash water consumption would not exceed 1% of the total water filtered on the average. The chemical consumption figures are also interesting. The average alumina dose was only 0.28 grains per gallon, and the average chlorine dose was 0.5 parts per million. The low consumption of alumina, thus is undoubtedly due to the method of mixing employed, and the special design of the settling tanks. The reason for the very low wash water consumption required, is due to the patented filter floors nozzles with separate orifices for the control of the air and wash water used for scouring, combined with the special horizontal wash system. A further economy is obtained by the installations of it, in slow start control, which makes it unnecessary to run the filtrate to waste after washing. The working costs of the installation is considerably less, due to

(1). Less quantity of air used for the air scour.

(2). Saving in power consumption, both on the air compressor and the wash water pump.

It is a recognised fact that a filter bed, after washing, is not working at its maximum efficiency, for a considerable period, depending upon the state of the raw water, and it is therefore necessary either to bring the filter slowly into operation over a period of from 30 to 60 minutes, or to run the first filtrate into waste. It was for this reason, the patent, Slow Start Control was produced, as it was almost impossible to carry out the operation satisfactorily by hand, particularly when reliance had to be placed upon semi-skilled labour.

Turbidity

During the period of the tests, the turbidity of the raw water varied between, 90 to 110 A.P.H.A. It was found that, with the Slow Start periods of less than 30 minutes, there was a definite tendency for dirty water to be delivered by the filter but that with slow start periods of 40 minutes and over, the colour of the filtrate never exceeded 3 A.P.H.A. and was less than this amount within about 45 minutes from the time of starting the filter, and at no time was it found necessary to run any of the filtrate to waste, although colour tests were taken every 5 minutes from the moment of starting up. In this connection, it should be mentioned that the recognised guarantee for a modern filter plant is to reduce the colour of the water to 10 A.P.H.A.

There appears to be ample justification for the installations of a control of this type on filters in India, where at any rate, during the monsoon period, the filters are dealing with a water of high turbidity, and where the importance of reducing the waste of water to a minimum is considerable.

The principles of iron eliminator treatment:—The first treatment which the water receives is aeration, which is the cheapest method of removing iron from water. This aeration is done in the upper chambers of the filter towers by spraying the water over the broken earthenware pipes cut into halves with which the chamber is filled. The amount of aeration which the water receives, has to be carefully controlled; since if the water receives too much aeration, the precipitate of iron oxide will form, before the water reaches the gravel bed, and the portion will pass through without clinging to the gravel. The trials made at Punta Gorda plant, Florida, showed that a 7 ft. depth of gravel bed was the best, and the rate of upward flow through it was found to be 2.5 gallons per minute per square foot of horizontal filter area, with means for clearing out the precipitate to be provided. Two usual methods of washing the filter

are found to be suitable. The first is the downward wash (at the rate of 450 gallons per minute) consists merely of opening a valve at the bottom and allowing the water lying above the gravel to flow back quickly through the gravel, and this has a good clearing action to enable the filter to continue working for many days. But when such action becomes inadequate, then an upward wash (at the rate of 750 gallons per minute) is done, i.e. passing upward through it a flow of clean water at 6 times the normal rate of flow, i.e. the rate of 15 gallons per minute per square foot. No chemicals are required for coagulation purposes, but only aeration and surface attraction are necessary. The action of the iron eliminator will best be understood from the accompanied diagram, showing a sectional elevation taken through one of the filters, and high lift pump house, as in Fig. 21.

Jalpaiguri (Northern Bengal) Water Works:— This water works was first designed in 1927, and the proposal was to draw water from a tube well, with the new method of water distribution, known as the decentralised storage system, at an estimated cost of Re. 1/- lakh. This water works is now a good example of the benefits of the decentralised storage system. The house holders with house connections get their supply of water, day and night from their roof tanks, and the street supply is also ample. The average supply (1936) was 4 to 5 gallons per head per day, but not exceeding 10 gallons per head per day. A good pressure is always maintained, and the pumping plant is not overtaxed. There are no meters with their attendant troubles of maintenance etc; hence it is the benefit of the decentralised storage system. The water was very soft, but contained iron in the proportion of 0.30 parts per 100,000. A treatment plant for the removal of iron salts is installed. Refer to January 1931 number of "American Water Works Journal," an iron eliminating plant at Punta Gorda, Florida.

The filter consists of a R. C. C. vertical cylinder, 13 ft. high, and 8 ft. internal diameter. Above the filter is the aerator, adding another 8½ ft. to the highest of the structure, the roof of the filter forming the floor of the aerator. The amount of aeration is regulated by the height of water in the aeration chamber (A), and this is controlled by varying the number of sections, in 4" vertical outlet pipe. By removing all the sections, the water level is lowered to the bottom, and the maximum aeration given of aeration chamber 'B' is isolated by a perforated wall. The outlet pipe 'C' is of 4" diameter, and ends over a 9" stand-pipe D. The water passes through a 6" valve E into 8" pipe under the filter, and thence the water passes up through 7 ft. of gravel, and discharges at the valve F, through 6" pipe to the second aerator at G. From this aerator, the water passes through a control chamber H, into the clean water reservoir, whence it is picked up by the high lift pumps, J and delivered through the 6" meter K, on 7" main to the town.

The filter plant consists of 2 upward flow gravel filters, each of 7000 gallons per hour capacity, through which the water from two tube wells is passed. The maximum supply to the town is at any rate up to 14,000 gallons per hour, at 2.5 gallons per minute per square foot, i.e. 150 gallons per hour —the number of square feet of horizontal filter area works out at 46.66, corresponding to a diameter of 7'-9". An 8 ft. diameter filter was adopted in order to provide a little margin. The gravel in these filter is graded as under:—

The bottom layer, 12" thick to the top of the manifold consists of large stones 2" to 3" diameter. Above this is a layer of 1" to 2" pebbles, 6" thick. The next layer is of ½" to 1" and 12" thick, the next ¼" to ½" and 24" thick, the next ⅓" to ¼" and 28" thick, and the top layer ½" to ⅛" and 2" and 2" thick. The maximum filtration head provided is 6 ft. and when that head is exceeded, the water overflows at

JALPAIGURI WATER SUPPLY
IRON ELIMINATION PLANT

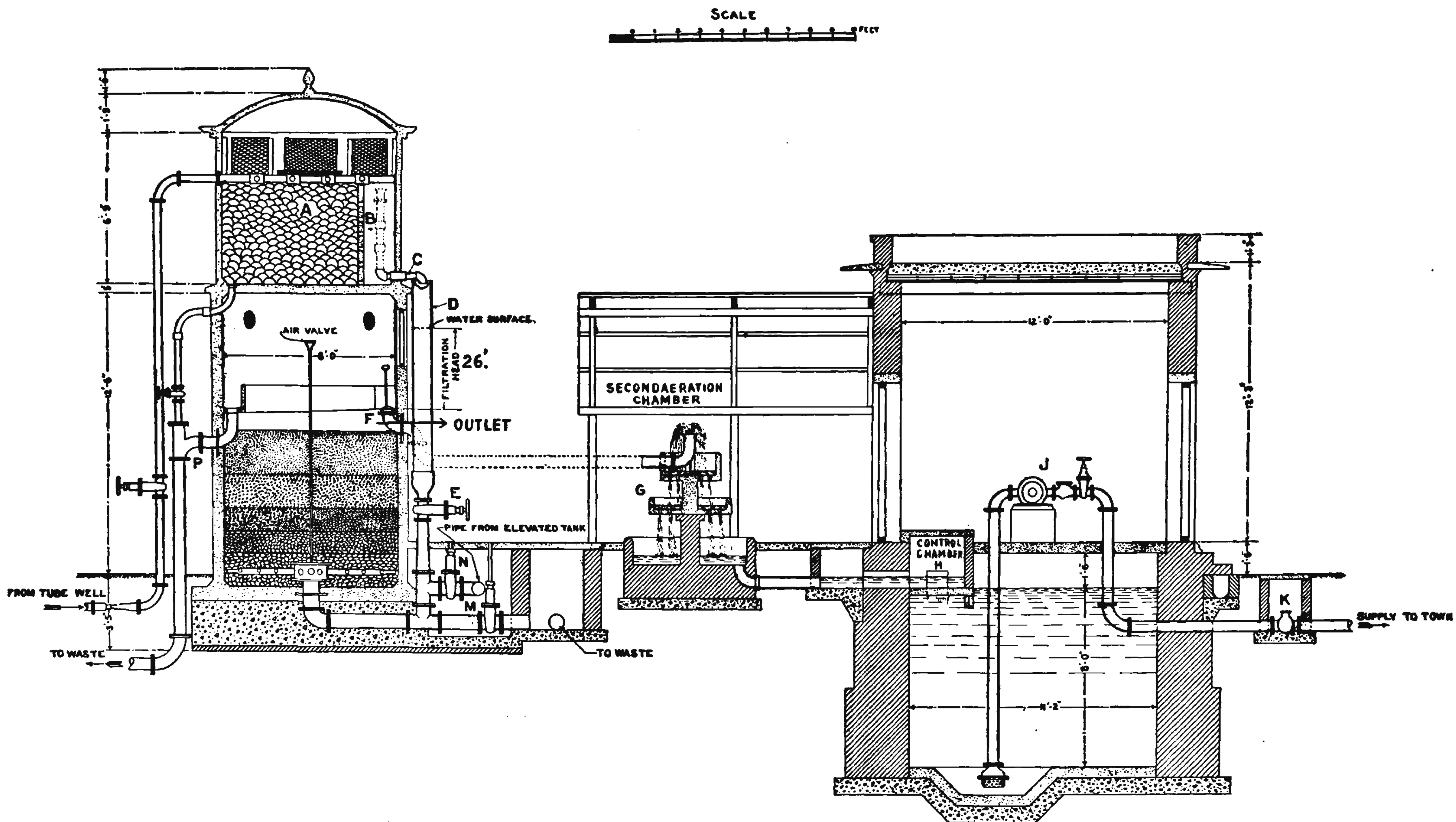

Fig. (21)

the top of the stand pipe. Such overflow shows that the filter requires washing. The washing, of course, is done before the stand pipe overflows, so as to avoid water wastage. The principal object of the second aerator (R. C. C. perforated tray as shown) is to remove any free CO_2 which may remain in the water. The aerator will require occasional cleaning, and this is done by placing a wooden plug in the outlet pipe, and opening the washout valve, then scraping and washing the surface of the aerator trays ,as may be necessary. The water from the two second aerators is gathered in the control chamber H, from which the Vitri chlorinator is operated. The rate of chlorination is proportional to the rate of flow of the water (M/s. Burn & Co.'s booklet).

Settling basins: The precipitate ladened water which runs to waste at the time of filter washing is carried to the settling basins, nearby the plant. In this basin, the precipitate settles, and the supernatent water is gradually drawn off. Eventually, the precipitate dries in the sun, and is removed and bagged, and it may be used for colouring cement, or for the paint manufacture or other purposes. This compares very favourably with any of the older methods of "Slow Sand" or rapid mechanical filtration." It would probably be safe to state here that the mechanical filters would cost from 2 to 3 times as much, but the maintenance cost of this plant is practically nil.

It is obvious that the same principles of design can be applied to much larger plants. A design has been prepared in 1935 to deal with a flow of 60,000 gallons per hour, the filter being divided into 6 sections, so that the flow direct from the pumps is sufficient to give the required rate of upwash in one section at a time. The filters can be made round or square, as the general principle of design is very flexible.

This plant was built by Messrs. Guba & Sons, of Calcutta. (see fig. 22).

Electrolytic chlorination of Gwalior Water Purification Plant:—

The water supply for Gwalior City with a population of about 2 lakhs is on the basis of 30 gallons per head per day, and the total capacity of water purification plant, is 4½ million gallons daily. The source of supply is Tigra tank of 4,600 million cubic feet maximum storage capacity, from where water reaches the filter by an open canal, 11 miles long, with the discharging capacity from 45 to 100 cusecs and is open to human and animal pollution. The filtration plant here is on the Boby system. Through the penstock regulating the filter inlet, the canal water flow is measured, when passing through the throat of the standing wave (hydraulic jump), flume added as a device by a Lea recording and integrating instrument (see fig. 25). The coagulant solution is dosed into the inlet channel just in front of the throat. The alum used as coagulant is dissolved in the elevated ferro concrete dissolving vats (3 in numbers), and then admitted into the three ferro concrete storage tanks. The alum solution diluted with water is fed through a constant level tank, and through the needle valve controlled by float, the alum is dosed into the inlet channel. This channel leads the dosed water into two coagulating tanks of 120' x 70' each, and are designed for 5 hours retention, at the maximum discharge of 5 million gallons per day. The tanks are sub-divided across by double walls into 3 compartments, the walls constraining the water to pass to the surface and then down to the bottom of the tank. The bottom of the tank is given slopes leading to the drain in the middle well (see fig. 24).

The water is decanted from the last section of the coagulating tanks over a concrete weir into the main filter feed channel with inlet sluice valves. The water is distributed over each filter area by means of ferro concrete troughs. There are five filter units, each of 27' x 20' in plan. The filter bed is made of

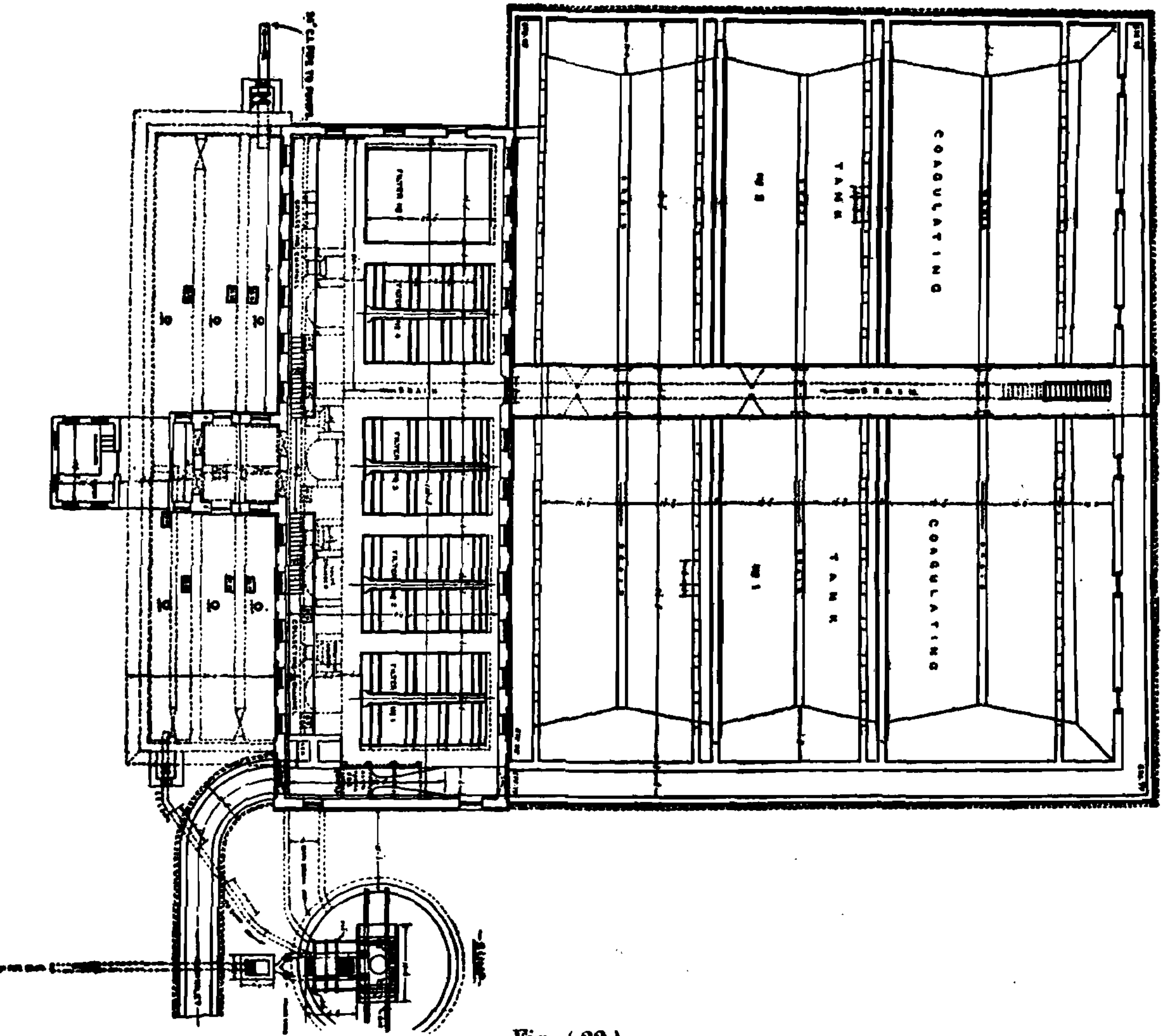

Fig. (22)

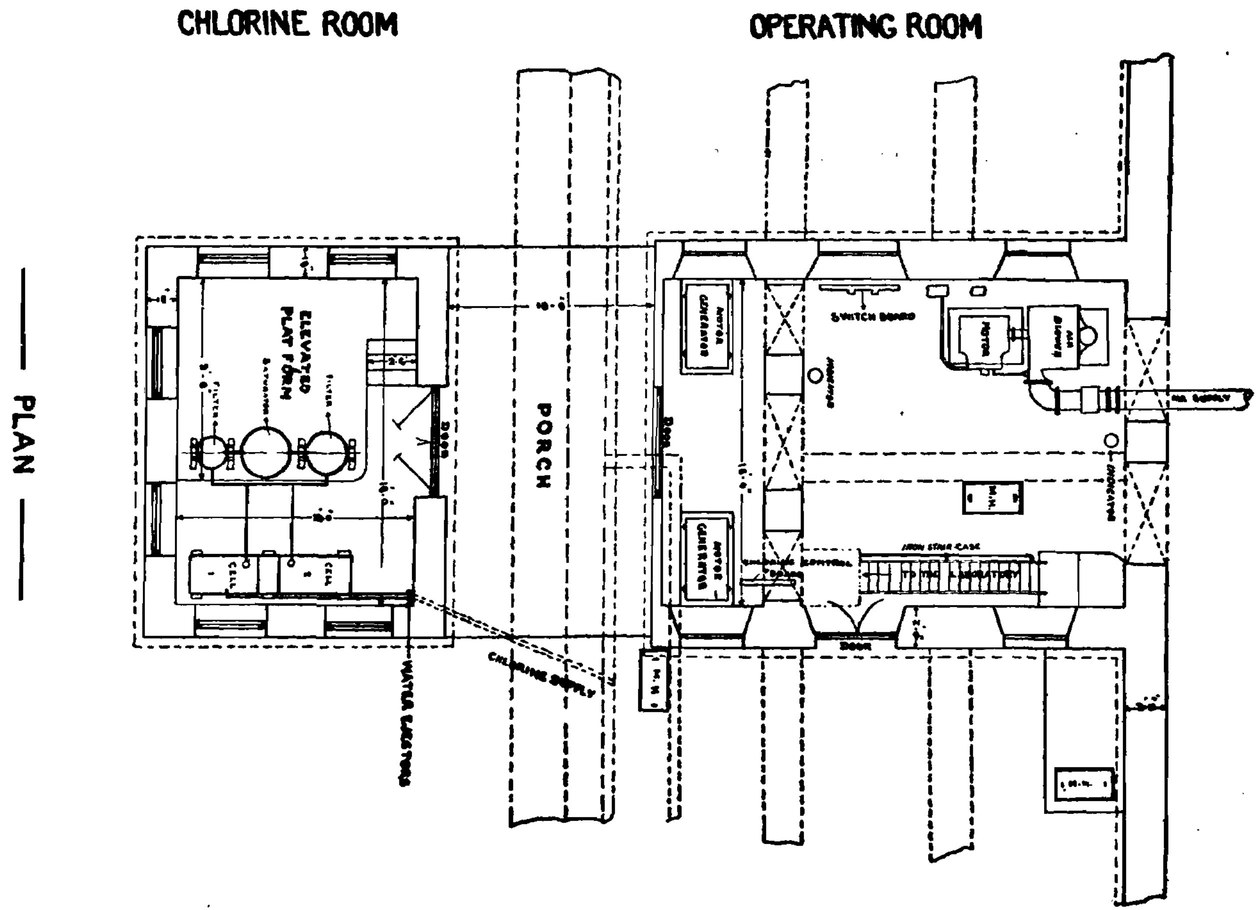
PLAN
CHLORINE ROOM
OPERATING ROOM
ELEVATED PLAT FORM
PORCH
SWITCH BOARD
MOTOR
MOTOR GENERATOR
IRON STAIR CASE
CHLORINE SUPPLY
WATER EJECTORS
DOOR

Fig. (23)

COAGULATION TANKS

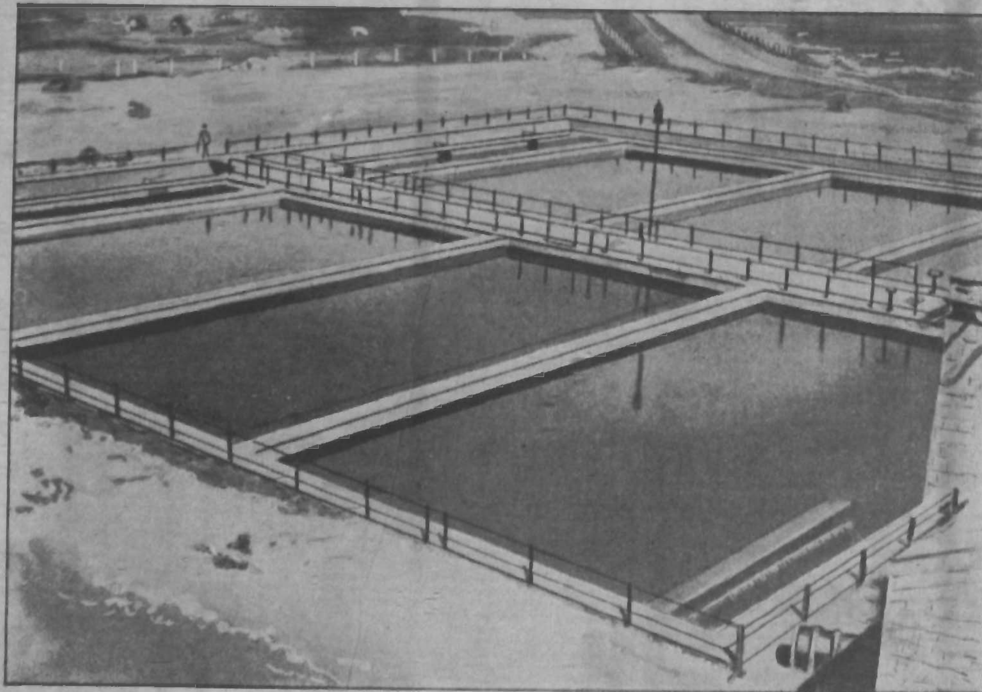

Fig. (24)

30" layer of sand (obtained partly by crushing white quartz stone, and part from Jhansi) over 14" layer of gravel. The sand is screened to pass 12 mesh, and to be retained on 28 mesh, with a specific gravity above 2.6. The gravel is graded from 2" at the bottom to ⅛" at the top of the layer. The filters are designed for the normal rate of filtration of 80 gallons per hour per square foot of area.

The filtered water is led into the underground circulating tank capable of holding half an hour's flow at maximum filtration rate. The 24" main leading to the pumps takes off from this tank. The sterilization of water by chlorine is effected, as the filtered water goes into the circulating tank, by means of a diffuser at the end of a rubber tube supplying chlorine. The chlorine gas is produced at site by electrolysis. The electrolysis chlorination for the disinfection of water is carried out in Gwalior water works and a plant comprising two 300 amperes sets, each producing 20 lbs. of chlorine gas per 24 hours, has been installed. The Gwalior experience, short as it has been, in addition to what is known of American practice, has without doubt established the fact that in the circumstances, the electrolysis chlorination proves to be the most suitable, and is to be preferred to other methods of water disinfection, because of cheaper cost, easier operation, reliability, absence of danger and easier storage. Refer an article in Vol. 17, No. 5, May 1927, of the American Waterworks Association, describing "Electrolytic Chlorine plant at Water Purification Plant at Sacramento, California."

Air agitation of the filter bed material is effected by means of an electrically driven air blower, (another feature uncommon for India), of 85 H. P., electric motor 110 amps, 400 volts driving at 2940 R. P. M. with a centrifugal air blower capable of delivering 2400 cubic feet of air per minute at 5 lbs/sq. in. pressure. This installation does away

with the troubles of attending the storage of compressed air. It however, throws for a couple of minutes a considerable load on to the power plant.

Standing wave flume (Hydraulic Jump) for mixing coagulants:

A comprehensive account of the use of hydraulic jump as a best mixing device at Kirtiland Pumping Station, Cleveland, Ohio, U. S. A. may be found in the journal of American Water Works Association, Vol. 17, January 1927.

The phenomenon, as defined in this paper, is due to conversion of a part of the kinetic energy of a stream of water flowing in a channel, at less than the critical depth, into potential energy in the turbulent passage from the lower to the upper alternative flow levels. This is utilized in India in distributing outlets for irrigation by Mr. C. C. Inglis, the then Superintendenting Engineer, Irrigation, Poona, and some of the data of his experiments were available, when designing the flume at Gwalior by Mr. S. T. Prokofieff as learnt (see fig. 25).

The general conclusions arrived at Kirtland, were that of extreme efficiency and great rapidity of the mixing of chemicals in the hydraulic jump as also that the loss of head through the jump is made lower than is produced in any conventional baffled mixing channel. The passage (of 44' length) through the hydraulic jump thoroughly aerates the water in addition to the extremely efficient mixing of coagulants.

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GWALIOR FILTRATION PLANT.
STANDING WAVE (HYDRAULIC JUMP) FLUME.

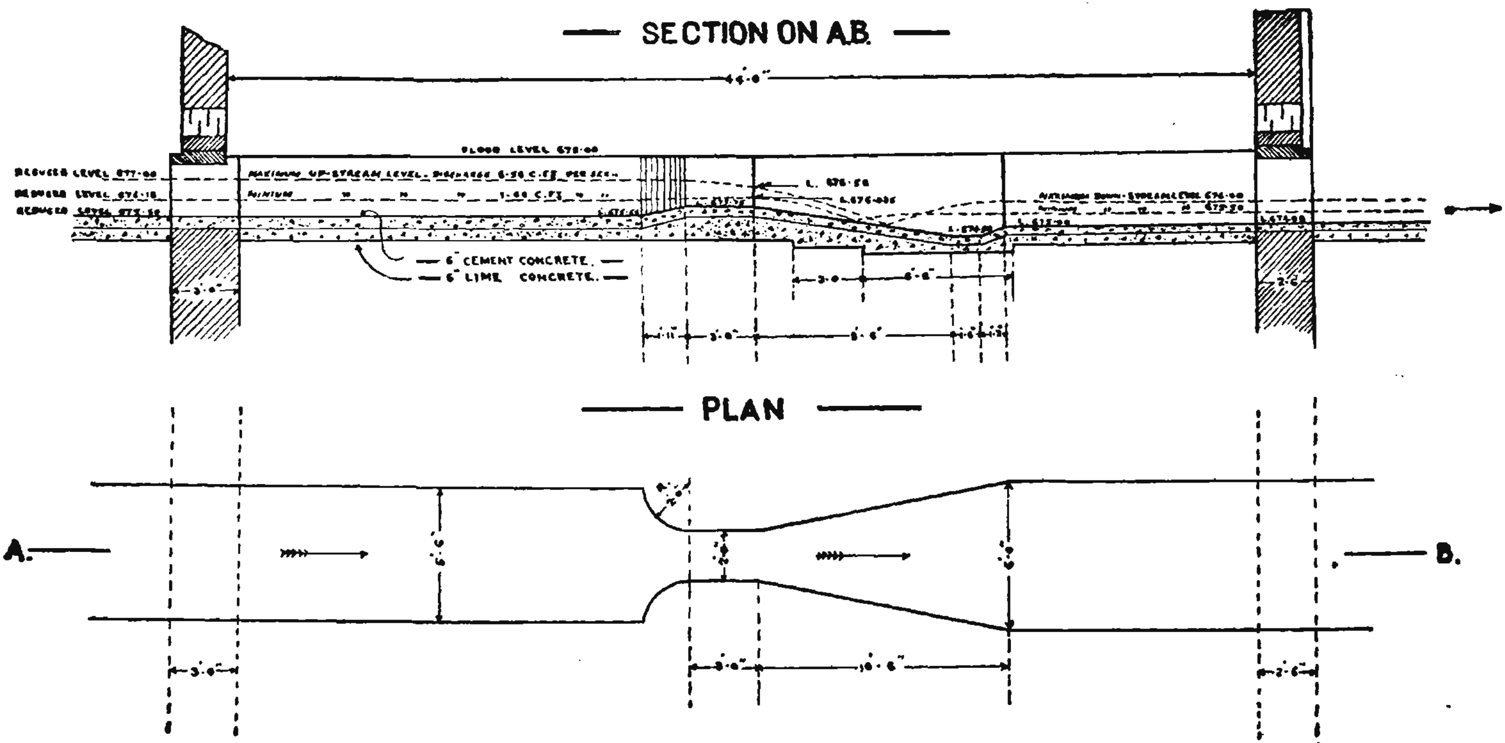

Fig. (25)

CHAPTER VIII.

PUMPS & PUMPING WATER

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PUMPS & PUMPING WATER

The word Pump, implies a machine for raising water from a well or underground source by means of the atmospheric pressure. The pumping machinery is one of the most important adjuncts of many Water Works, and that, the breakdown of such pumping machinery, may mean a complete stoppage of water supply, and water famine. It is, therefore, of the utmost importance that the Pumping Machinery be reliable, and of very good make.

Although the gravitational Water Supply Scheme is always to be preferred to a pumping scheme, still the latter is often the only economical way of obtaining the water supply. The question of utilising the gravitational supply, where such is available, requires careful consideration, as it is largely a matter of the comparative costs of the two systems.

For a small town usually, it does not pay to lay water mains for any considerable distance to get water from the catchment area, while in the case of large cities, such as Calcutta, Hyderabad (Deccan), Indore, Satkhira (wells), Mhow, Bombay, etc., it has been found sound policy to bring the water from a long distance. In many cases, Mhow for instance, the only available supply is a gravitational scheme, whose storage reservoir is many miles away. The pumping of water, in the further parts of the supply, entails considerable expense particularly where the cost of fuel is high. On the other hand, when once the gravitational scheme is well installed, the cost of the Maintenance is small compared with the interest on the capital outlay.

The deciding factor, where both systems are available, and taking into account present and future needs or requirements, is whether the annual cost

of pumping, plus the interest on the cost of pumping plant will be less than the annual interest on the capital expended on a gravitational scheme. The second important factors entering into the whole question are:—Local Conditions Cost of Fuel at the Pumping Station, Maximum head to which delivery is required, and the possibility of getting the machinery transported (in case of Works abroad). In some cases, it may pay to put down Pumps to supply certain high level zones or areas, to supplement the gravity systems by forcing the water to the higher portions of the town, which cannot be supplied by the gravity system. Gravitational System cannot be applied, in many cases, owing to (1) there being not any catchment area at a suitable elevation to supply the area, in question. (2) there being no facilities for impounding water. The living example of this kind is London, where the whole of the water is obtained by pumping, a certain amount being taken from the "Rivers" Thames & Lea. and the remaining from numerous wells sunk around London, tapping all the water bearing strata. About 130 million gallons of water daily are drawn from the River Thames

If pumping is used to raise water to the necessary height, it should be in duplicate, so that a breakdown in one set will not lead to the immediate cessation of the city supply.

Hawksley's formula for head in feet absorbed by friction is easy to remember, use and sufficiently accurate for small work. It is:

$$\left(\frac{\text{Galls./minute}^2 \times \text{ length in yards.}}{243 \times \text{ diameter in inches}^5}\right)$$

After deciding to supply by pumping, the following three main items have to be very carefully considered, as:

(1) *Reliability*:—It is of the first importance. The Engineer must feel sure that the whole plant

is reliable, *i.e.* the plant must be able to run it continuously for long periods without, say, stoppages, for oiling, cleaning, adjustment or breakdown.

(2) *Efficiency*:—It is measured by the quantity of water to be raised to the required height for a given expenditure of fuel, and the more water so raised the higher is the efficiency. Water Works pumping plants are working more or less day & night, and an increase of even 1 per cent. in efficiency in a large installation will make a considerable saving in fuel bill per year.

(3) *Maintenances*—The Pumping Plant chosen must not be complicated, but of a simple type in which the cost of maintenance is small. Many Water Works Engineers make a pumping station a show place, and have highly decorative and polished work on the machines, and in the Engine-room. All this means extra attendants to keep the work and decorations clean, and serves no useful purpose.

This subject is, also, therefore of vital interest to Agriculturists, Irrigation Engineers and House-holders in large cities. The Civil, Municipal and Sanitary Engineers should have some knowledge of the principles of pumping machinery, and it is not absolutely necessary that they should understand all details, these being a department of Mechanical Engineering.

Now the most important points to be considered in installing the Pumps are:—(1) Quantity of water to be dealt with, usually in gallons per minute. (2) Difference in levels between the surface of the source of supply and the highest point of delivery or alternatively, the difference in pressures at these two points. (3) The type and size of the pipes to be used, both between the source of supply and the pump, and between the pump and the point of delivery. (4) Nature and condition of the liquid to be pumped. (5) Method of driving the pump.

The force required to pump is that necessary (1) to raise the water by suction into cylinder (2) to raise it by pressure against the head of water above it (3) to overcome the friction in pipes (4) to overcome the inertia of all water moved (5) the friction and inertia of all water moved (6) the friction of all water passing through the pump.

Note:— The first three are useful work performed by the pump, and credited to it. The others are energy used by the pump, and charged against it.

Classification of Pumps:—It would be beyond the scope here to deal in a detailed way, but a few brief notes may be of interest. The Authors consider that there are distinct advantages in the vertical form. It is summarized under the following headings:—(1) Vertical (2) Horizontal pumps. (3) Centrifugal pumps (4) Rotary (5) Pulsometer type Pumps.

(1) *"Vertical pumps" are:*—(a) Ordinary suction or Bucket pumps, (*b*) Suction and Lift (sometimes called Lift and Force Pumps) (c) Plunger or Force Pumps, (*d*) Bucket and Plunger or Bucket and Ram Pumps, (*e*) Piston and Plunger or Piston and Ram Pumps.

(2) *Horizontal Pumps are:*—(*a*) Double acting piston pumps, (*b*) Single acting plunger or ram pumps, (*c*) Double acting plunger or ram pumps, (*d*) Bucket and plunger pumps or reciprocating pumps, (*e*) Piston and plunger pumps.

Horizontal bucket pumps do not work well, because bucket valve does not work well, in horizontal position, but the bucket pumps in the vertical position work excellently, as there is no possibility of air lodging anywhere, also if well designed very little clearance space is necessary. The disadvantage of this pump is great wear and tear on bucket leathers or rings and contracted way through the buckets.

The force is applied to a liquid through the medium of a pump in two modes: (1) To bring the liquid upon a piston working up and down in a cylinder to the upper end of which a pipe is fixed, the upward motion of the piston then raises the water at every successive stroke, until it eventually reaches the top of the cylinder or pipe. Pumps of this kind are called, "Lift Pumps", because the liquid is lifted up by the piston or bucket to the required height, (height is limited only by the strength of the materials and the force available) The atmospheric pressure is employed to raise the water, a portion of the height. The part of the pump, which is below the bucket is called the Suction, and that above it called the lift. (2) Applying force to the liquid by means of a pump is to bring the fluid beneath the piston working up and down inside the cylinder the downward movement or stroke of the piston forcing the fluid up through a pipe provided. The pump of this kind is called a Force Pump.

Horizontal single acting ram pumps are seldom used, except for boiler feeding. The ram pump speed varies from 300 to 350 ft. head.

Double acting plunger pumps:—They are mostly used horizontally, are excellent for sandy, gritty and dirty water, and sometimes are used for air compressing and are divided into those (*a*) with internally packed, (*b*) Externally packed. The advantage of (*a*) is that the size of the plunger can be changed quickly by fixing another bush of larger or smaller bore or new plunger to suit it. Now the disadvantage is that it is only suitable for low lifts, as having no packing. A leak may develop, and go on for a long time without being detected.

(*a*) *Ordinary bucket or suction pumps*:—It is the ordinary hand pump used for wells and particularly for the shallow well tanks, etc., for delivering water at the pump level.

(*b*) *Lift and Suction Pumps:*—It is one having of better construction for delivering water at levels above the pump.

(c) *Plunger or Force Pump:*—It is chiefly used as the boiler feed pump or delivering small quantities of water, and larger sizes are used on mines.

(*d*) *Vertical hollow plunger pump:*—Is the combination of the bucket and plunger pump. The plunger generally consists of a hollow cylinder without flanges turned all over perfectly true and parallel, furnished at the top and bottom in the inside with begs for attaching the pump rods by means of double nuts at the top and by means of a forged crosshead on the main pump rod fixed by double nuts. The delivery valve is simply a round leather faced disc sliding on the two plunger rods and a cross piece secured to the rods by cotters is provided for determining the lift of the valve.

The advantage of hollow over solid ram is that water is continuously rising in the direction of travel, and is not met with by a flat plunger, which reverses the flow causing shhock and increased friction and consequent reducing the outflow.

The vertical bucket and Plunger Pumps:—It really makes a single acting, into the double acting so that the water is delivered both on the up and down strokes. This pump is largely used in the Engineering works. Generally speaking, the plunger pump has a greater efficiency for high lifts, than the centrifugal pump, on account of the slip which takes place in the latter.

Horizontal single acting pumps work in connection with one set of valves, inlet and outlet, and the return stroke is negative, because the water becomes stationary (during the downward stroke). This is very objectionable as the inertia of the water in the pipes has to be overcome with each stroke, causing a pulsation and water-hammer. To overcome this,

two, three, or even four pumps cylinders are connected with the feed or suction pipe, and the delivery or rising main, so arranged that when one barrel is giving a minimum, the other is giving a maximum discharge, so as to equalise this discharge or flow. It also economises the power required. The speed for the single acting pump varies from 80 to 100 ft. per minute. The triple acting single pump is equally good as the double acting pump, (all positive strokes). In double acting pump, due to all positive strokes, the great advantage of it is that the water is in constant motion with a uniform delivery. It takes up small space, and the speed varies from 60 to 100 ft. per minute. To reduce the shocks in the velocity main and to cause the flow to be more uniform and steady which are the main functions of an air vessel, and air chamber or air vessel is employed. It is very necessary also in the case of any pump connected even to a long delivery pipe. It is generally fixed in the rising main which greatly assists to equalise the flow, and to increase the efficiency of the pump.

The suction pipe is usually smaller than the pump barrel. Its diameter must be half that of the pump to get good and satisfactory results. If very long, then it should be increased by one size.

The bucket and the plunger pump or reciprocating pump is also known as the Continuous Flow Pump. The bucket and the plunger are raised together, both will suck and fill the working barrels, with the liquid they are raising. When descend, the plunger forces the liquid up through the bucket, therefore the water out of one barrel will be forced into the raising main and the barrel above the bucket, and on the next upward stroke, water in it will be lifted into the rising main. By this, it will be seen that the water continuously is flowing up through the delivery pipe. In this, the reciprocating part is caused to move to and fro. .

The advantage of this pump is the continuous flow into the delivery pipe, thereby preventing shocks. Some pumps are designed and made such that water will flow in the same direction, thus preventing the shocks in the pumps themselves.

In new pumps or during dry weather, the valves and pumps become hard and dried, so much so that they do not form air-tight joints, and again, in some cases should the height of the lower valve exceed 24 ft. to 26 ft., the pump will fail to raise the water, although if once started it would continue to work. In some cases—the way to start the pump is by pouring water through the tap of the pump into the barrel. This is called priming the pump.

It is not desirable to use a pump of smaller barrel than about 2½″ as the waterways are contracted in the small ones, and the friction is increased. It is better always to use a larger pump driven more slowly. The suction and the delivery pipes of pumps should not be less than ½ of the diameter of the barrels. The suction pipe should also be larger than the delivery pipe as in the suction pipe, there is only the atmospheric pressure to overcome the friction, whereas in the delivery pipe there is the whole power of the pump. The following is the table for information:—

(1) Size of the pump barrel ..	2″	2½″	3″	3½″	4″	5″	6″
(2) Size of the Suction pipe ..	1¼″	1½″	2″	2″	2½″	3″	4″
(3) Size of delivery pipe ..	1″	1″	1″	1″	1½″	1½″	2″

The difference between the displacement and the actual discharge expressed as a percentage of the dis-

placement, is called the Slip of the Pump. When the column of the water in the suction and discharge pipe of a pump is long and lift moderate, the energy imparted by the piston during the discharge stroke is sufficient to keep the column of water in motion during all or a part of the return stroke. The slip therefore varies considerably depending on the tightness of the valves, piston etc., but in well constructed pumps, it should not exceed 5%.

Centrifugal Pumps:—Reciprocating pumps may be considered as reversed pressure motors. A pressure motor, if driven from some external source becomes a pump; the feed pipe of the motor become the suction pipe of the pump, and the exhaust pipe becomes the delivery pipe. Likewise, the Centrifugal pump is also considered as a reversed velocity motor. In the motor, water gives up Kinetic Energy due to its velocity, and from this Kinetic energy is obtained the work required to drive the moving parts.

In the Centrifugal pump the action is reversed, the water enters with little velocity and at atmospheric pressure, work is done on it by the vanes of the impeller, wheel or fan or the pump, and it leaves the pump with a higher velocity and higher pressure. By virtue of this increased velocity and pressure, water is enabled to rise to the upper level. As the water rises, its Kinetic and pressure energies are converted into the Potential Energy. The rotary vanes mounted on a spindle, *i.e.*, impellers are the main points to be considered in the Contrifugal Pumps. The fundamental principles applied to all Centrifugal pumps are—Pump being charged with the water, the impeller or fan is set in motion at a great speed, imparting Centrifugal motion to the water contained in the impeller and so driven into the casing or body of the pump, by the partial vacuum, thus created in the impeller, the water is forced up the suction pipe by the atmospheric pres-

sure. The water entering the disc receives again a centrifugal motion, and by this means a continuous stream is received into, and discharged from the pump.

The scientifically designed vanes have efficiency upto 86 per cent as claimed and this is not always attained in practice, yet a very satisfactory efficiency of 70 per cent may be obtained from a pump which is correctly designed for the work it has to do. But for low lifts upto say 30 ft. the centrifugal pump is considered the most efficient. The multistage turbine pumps are used for high lifts upto 200 to 250 ft.

The advantages of the centrifugal pump are:—(1) Large body of water, which it is capable of delivering, as compared with its size and prime cost. (2) Can deliver sandy, gritty and muddy water, without any injury to the pump. (3) Easy to fix, and requires very small, and inexpensive foundations. (4) Suitable for high speeds.

The disadvantage of the Centrifugal pump is that, it cannot raise water to any great height, due to the low suction heads, *i.e.*, 18 to 20 ft. and priming.

The losses in the Centrifugal pumps are, the head reduced by friction, leakage, diffusion, and angle of vanes.

In comparing the Centrifugal pumps with the ordinary Reciprocating pumps we find that for the lifts above 20 ft., the results are in favour of reciprocating pumps under 20 ft., the two classes of pumps are equal, but for lifts of 4 to 5 ft. centrifugal pumps have a most decided advantage.

No foot valve is required in case of the submerged centrifugal pump, where muddy and impure water is to be pumped, and no charging or priming is required for starting it.

For the high lift, the ordinary form of the centrifugal pump is not satisfactory, due chiefly to the

rapid fall in efficiency, as the lift and the peripherial speed of the impeller becomes higher, a modified type of pump has been developed, as Single Stage, and the Multi Stage, the inventor being a French Engineer by name Rateau. The multiple stage, type of the Centrifugal pump is largely used for lifts of 350-400 ft., and has proved quite satisfactory for lifts upto 1000 ft. The 30 ft. head is the maximum limit, which the single stage centrifugal pump can efficiently pump, the design is the same, but the only difference in the single stage and the multi-stage is in Balancing (i.e. side thrust), by an even number of impellers.

A centrifugal pump will not begin to lift until the chamber in which the impeller revolves is full of water. Unless the water is arranged to flow into the pump, it is usual to provide the larger sizes with a stream jet, whereby the air is drawn from the pump, and water caused to enter the suction pipe, smaller sizes are filled by hand. For these reasons, before deciding to install centrifugal pumps for a Water Works Supply, the suitability of the pumps to work under the conditions *obtaining should be carefully considered.* Where long suction pipes are necessary, the direct acting pump motion is by far the best, because the speed of the water is constant through the entire length of the stroke.

Air lift pump is suitable for small water supplies drawn from the artesian wells or bore holes, but would not be applicable in case of large water works. The great superiority of the air lift over any other type of pumping plant for tube well is that there is no limit to the depression head, that can be put on a well, provided the well is deep enough for adequate submergence of the air pipe, and that no damage can occur due to the unflow of sand, as no working parts of the machinery come in contact with it, as per the remarks of the Superintending Engineer, Mr. H. G. Trivedi, Public

Health Engineering Department, Govt. of U. P., in his paper on "Open end type tube wells" read before the Institution of Engineers (India). The best examples of tube well supply are Unao and Hathras of U. P.

The accessories to a pump should include a stop valve on the main supply pipe; a foot valve or non-return valve on the suction, and lastly a strainer. The foot valve is necessary to hold or retain water in the suction pipe, when the pump is working, so that it will not draw air when starting. A cock is necessary on the suction pipe to allow it to be filled, if by chance it gets empty or at starting. Lastly, a strainer usually of a cast iron ball shaped chamber with holes of ⅜" diameter, and the total area of these ⅜" holes should be at least 1½ times that of the suction pipe area.

Pump Valves:—are the most important parts of the pump. The duty of the valve is twofold; (1) It should afford an unobstructed passage for the water in one direction (must move with the same velocity as the water); (2) It should close the passage entirely and prevent the return in the contrary direction (heavy enough generally to close by its own weight).

An ideal motive power for driving moderate sized pumps is electricity in general, where cheap current is available. Where current is not available or cheap gas or oil engines generally offer the most suitable power for small and medium sized plants. Steam engines for larger plants offer the most reliable and economical form of power.

The following are the Standard Formulae used in designing Centrifugal Pumps:—Let us take an example, to design a low lift Centrifugal Pump for raising water to a height of 15 ft. so as to discharge 4000 gallons of water per minute.

Solution:—Velocity $= 8\sqrt{H+K}$; where, V = Velocity in ft./second, H = Head in ft.; (but to this, add 20% for friction losses, etc.), K = Constant, varying from 5 to 10 (smaller figure for lower lifts).

Now by applying this formula.

$$V = 8\sqrt{H} + K$$

$$V = 8\sqrt{15} + 3 + 6$$

$$V = 8 \times 4.2 + 6 = \underline{39.6 \text{ say } 40 \text{ ft. per second.}}$$

Now, find out the diameter of the discharge pipe (take 8 ft./second) by the formula:—

$$Q = \frac{\text{Gallons per minute}}{6.25 \times 60}$$

$$Q == 10.66 \text{ cu. ft. per second}$$

$$\text{Area of the pipe} = \frac{10.66}{8} = 1.33 \text{ sq. ft.}$$

$$\text{Pipe diameter, } D^2 \times .7854 = \text{area,}$$
$$D^2 \times .7854 = 1.33$$
$$\therefore \quad \underline{\text{Dia.} = 16 \text{ inches.}}$$

If the disc is made 3 times the diameter of suction (generally) therefore, the disc diameter
$= 3 \times 16'' = 48'' = 4$ ft.

As a rule, the diameter of the fan or disc varies 1½ to 5 times the inlet diameter

$$\therefore \text{No. of revolutions} = \frac{\text{Fan speed or Vel. in ft./sec.} \times 60}{\text{circumference of fan in ft. (HD)}}$$

$$\frac{40 \times 60}{4 \times 3.146} = \frac{2400}{12{\cdot}5664}$$

$\therefore$ No. of revolutions = 192 per minute
Width of the fan at periphery W,

$$W = \frac{A}{C} = \frac{\text{area of discharge pipe in sq. ft.}}{\text{circumference of fan in ft.—6 blades thickness.}}$$

assume blades $\frac{1}{2}''$ thick, and 6 blades, *i.e.* $6 \times \frac{1}{2}''$
$= 3''$ or $= \cdot 25$ ft.

$$\therefore \text{ Width} = \frac{1{\cdot}33 \times 12}{12{\cdot}56 - {\cdot}25} = \frac{15{\cdot}96}{12{\cdot}31} = 1{\cdot}296 \text{ ft.}$$

Width $= 1.296$ ft. $= 1\frac{3}{8}''$

Diameter of the discharge pipe $= 16''$
Diameter of the fan or disc $= 4$ ft.
Width of the fan at periphery $= 1\frac{3}{8}''$
No. of revolutions per minute $= 192$ } **Answer.**

Calculations for High Lifts Examples:—Design a Centrifugal pump, to pump water to a height of 40 ft., so as to discharge 1,000 gallons of water per minute, taking flow as 5 ft. per second.

Solution:—Velocity $= 8\sqrt{H + K} = 8\sqrt{40 + 8} + 6$
Vel. $= 8 \times 6.9 + 6 = 61.2$ say 62 ft. per second.

Vel$=62$ ft. per second.

$$\text{Discharge} = \frac{1000}{6{\cdot}25 \times 60} = \frac{100}{375} = 2{\cdot}66 \text{ cu. ft. per second.}$$

$$\therefore \text{ Area of the pipe} = \frac{2{\cdot}66}{5} = 0{\cdot}53 \text{ sq. ft. and so diameter}$$

of pipe will be as $D^2 \times {\cdot}7854 = 0.53$.

$$\therefore D^2 = \frac{0{\cdot}53}{0{\cdot}7854} = 0{\cdot}67.$$

$$D = \sqrt{.67} = 0.8 \text{ ft.}$$

$$D = 9.6'' \text{ say } 10 \text{ inches.}$$

Now disc diameter will be$=3 \times 10 = 30'' = 2\frac{1}{2}$ ft.

$$\text{No of revolution} = \frac{62 \times 60}{5/2 \times 3{\cdot}1416} = \frac{3720 \times 2}{15{\cdot}708}$$

$=473.7$ say 500 per minute.

No. of revolutions $= 500$ per minute

$$\text{Width of fan or disc} = \frac{A}{C} = \frac{0{\cdot}53 \times 12}{7{\cdot}75 - {\cdot}25} = \frac{6.36}{7.50} = .85 \text{ ft,}$$

Width $= .85$ ft. or $\frac{7}{8}''$ thick.

Diameter of discharge pipe = 10″
Diameter of disc or fan = 2½ ft.
No. of **revolutions** = **500**
Width of fan or disc = ⅞″. } **Answer.**

Calculation for pumps (Water Supply Scheme)

Example:—Find the number of gallons discharged by a pump, 12″ diameter, of 80 ft. per minute say the piston speed.

Solution:—Pump *barrel or diameter* of pump in Inches^2 } × .034 × **piston speed in ft.**

Discharge = 12″ × 12″ × .034 × 80
= 396 gallons per minute, i.e.

Say 400 gallons/minute

400 gallons/minute
× 60

24,000 gallons per hour.

Now, in practice, the pumps are designed to work for 6 hours per day can increase to 8 hours to keep pace with the increase of the population.

i.e. 24,000 gallons per hour
× 6 hours (working hours of the pump)

144,000 gallons per day per barrel
× 3 gallons per day for treble barrel acting pump

432,000
—60,000 Deduct 15% for slip

372,000 gallons per day Answer.

The works of the French Engineers, Messrs. Defield and Oliver in this respect worth a glance.

The paper on "Practical Hints on the Centrifugal pumping, read by Mr. V. R. Blundell, M.C., A.M.I.M.E., A.M.I.E.E., at the 19th Annual Conference of the Mechanical Engineers' Association (India) on 17-2-1939 under the Presidentship of Mr. A. S.

Trollip, B.Sc. (Lon.), etc., General Manager of B.E.S.T. Co., Ltd., and the lecture on this subject was also delivered by Mr. V. R. Blundell before the Bombay Engineering Congress on 4-11-1938, will be worth reading.

On the method of driving, Mr. Blundell remarked that the Centrifugal pump was particularly suited for high speeds, and therefore for driving from electric motors and steam turbines. On account of the small inertia of the moving parts, a Centrifugal pump could be started very rapidly, a point suitable for induction motor drives.

Concluding, Mr. Blundell declared that the Centrifugal pump was very simple in construction, very compact, and that its maintenance cost was remarkably low.

The application of the Centrifugal pump is very large, and the authors have only to consider Town Water Supply. In Calcutta, all the water for the town supply is to be lifted from the river Hooghley of Palta. To the authors' knowledge 8400 H.P. of Centrifugal pumps are installed for the filtered water supply alone in that city, together with considerably over 3,500 H.P. of centrifugal pumps for the unfiltered water supply, which is used for sanitary (flushing etc.) purposes.

Centrifugal pumps are also largely used for the pumping of the Sewage over the plunger pumps used exclusively for the sewage pumping in good old times, partly because the wear and tear is not so great as in the case of the piston pumps, and partly because, owing to the high rate of speed at which Centrifugal pumps run, and can be driven directly from electric motors. They are also, on this account, more silent in their working, and so can be placed without inconvenience in positions where the noise and vibration caused by thrust of the plunger pump has a greater efficiency for high

lifts, than the Centrifugal pump, on account of the slip which takes place in the latter. One great drawback of the plunger pump is that the sewage must be well screened to arrest any large solid matters, as rags, pieces of paper, etc., which would interfere with the working of the valves. With large Centrifugal pumps such careful screening is not necessary due to the absence of the valves, and they are better able to deal with such matters. It is advisable in the case of small pumps, in which pieces of paper rags, etc., are liable to get caught in the vanes.

Pumps of the Pulsometer Type are useful for many purposes in connection with water works, as with so many branches of engineering, and especially for temporary works or where it is necessary frequently to change the suction pipe, or even of the pump, but they are not to be recommended for the constant work. This type of pump is used, where large quantities of water have to be pumped, it will probably be more economical to do it by means of machine driven pumps. Pulsometer pump has the great advantage that it may be suspended from a chain, and is therefore very much more easily moved from place to place than any of the pumps.

The World's largest Centrifugal Pumps are installed for the Fen Drainage System in England, at St. Germans near Kings Lynn, and it will be of interest to state briefly. The district with which this is concerned is known as the Middle Level, the drainage area of which is some 173,000 acres in extent, and comprises a flat expanse of Fen Land lying several feet below the high water tide levels of the adjacent rivers Nene and Ouse. Due to the gradual silting up of the rivers and the shrinkage of the fens themselves, the problem of disposing of the drainage waters has become more acute every year, and the existing arrangements would be unable to cope

with the problem. In 1848, a sluice valve was built to control the flow of water, but some disaster overtook it in 1862, when it burst, and as a consequence about 900 acres of land were flooded. A second sluice was built in 1875 to relieve a battery of syphon sluices but which had become silted up. This had proved to be satisfactory until 1928, when as has already been stated, silting up of the rivers and shrinkage of the fens has rendered it obsolete.

In 1929, the Middle Level Commissioners, on the advice of their Chief Engineer, decided to embark on the new scheme. It will be realised from above that a sluice alone would not be satisfactory, as at certain conditions of the tide, there is no longer sufficient hydraulic gradient to enable the drain to flow naturally, and the volume of the water to be dealt with daily is such that continuous flow is essential. It was, therefore, decided to erect a combined sluice and pumping station. Several schemes were considered, but the chief difficulty was to design the suitable pumps, having and satisfactory efficiency combined with the capability of dealing with the immense volume of water against comparatively low heads. After several manufacturers and experts had been consulted, it was decided to adopt the designs of M|s. Guynnes Pumps Ltd. of London, whose reputation as Centrifugal Pump makers of over 90 years standing no doubt was a factor in their being selected. The pumps of which there are three, are of special interest, in that they are the largest Centrifugal pumps ever built in England. Each pump weighs about 64 tons, and has a delivery branch 102″ in diameter, the photograph below of one pump gives an idea of its immense size.

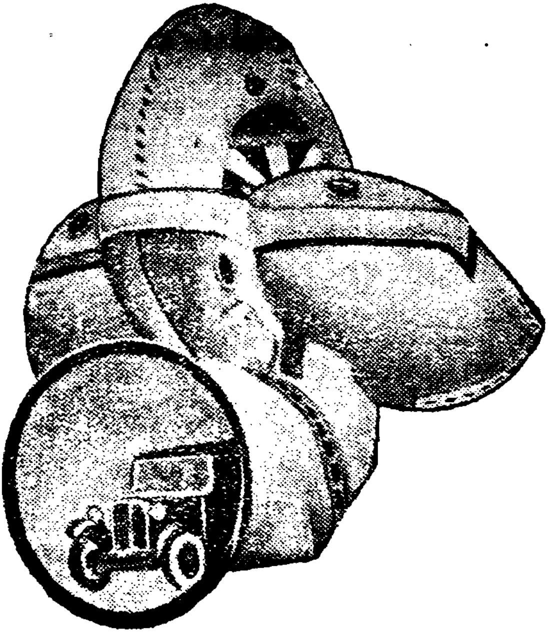

Fig. (21)

When the drawings and calculations had been finally completed, a model of the pump was made by M|s. Guynnes Pumps Ltd., and tested at their Lincoln Works, and it is extremely interesting to note that the test figures showed that the claims of the design department in regard to the efficiency and outputs were fully upheld, although at the outset several experts were somewhat doubtful as to whether a Centrifugal pump could be designed to perform the required duty satisfactorily. Worthington Simpson Ltd. of Newaile-on-Tent have completed in the year 1941, the installation and started up a large vertical pumping plant at an important water works in the South of England. See Water

and Water Engineering, Vol. XLIII, No. 546 for the description.

Booster pumps are very often installed on water supply mains to increase the pressure to certain districts when the demands for a supply at a higher level than originally anticipated in the scheme. These are almost invariably Centrifugal pumps, and the booster takes the form of a high lift Centrifugal pump, with its suction on the upstream side of the water main and its delivery on the down stream side of the water main. A paper read on "Pressure Boosting Station for the Walter Works of the city of Monte Video" by Arthur Honey Sett, A.M.I.C.E., (Proceedings of the Institution of Civil Engineers, London, Vol. 221, Page 123) is also interesting, and worth a glance.

Hydraulic Rams—is an automatic machine, and is extremely used for raising water to a height considerably above the top of the fall available as motive power, and not for pumping very large quantities of water. It is used where sufficient quantity of water is available for working the hydraulic rams. The principle underlying their construction is that of using the momentum (Mass $\times$ Velocity) of a body of water falling through an inclined pipe to raise a smaller quantity of water through a great height. It is very suitable for automatically raising water for supplying Mansions, Farms, Hotels, etc.

With a well-designed hydraulic ram working under suitable conditions, it is possible to raise about one seventh of the volume of the supply water to about four times the height of the supply. One fourteenth of the water can be raised to a level above the ram, eight times as high as the fall to the ram. It can be used advantageously, of course, where the supply available is considerably in excess of what is required. For every 1 ft. of head, water is raised to over 50 ft. height.

The advantage of the Hydraulic ram over the **pumps are as under:—**

Pumps.

1. Maintenance very costly.
2. Motive power is required.
3. Attention, (necessary during running pumps.)
4. Reliability is less.
5. Waste of water practically none.
6. Cost of repairs, being great.

Hydraulic Rams.

1. Very economical.
2. Automatic.
3. Practically none.
4. Reliability (much more.)
5. $\frac{3}{4}$ is watered (roughly).
6. Cost of repairs, being very less.

Pumping Machineries

The decision as to whether the Diesel oil Engine, a Steam Engine, a Centrifugal Pump, directly coupled to an Electric Motor, or an Air-Compressor has to be selected depends on the existing circumstances. For a very small Plant Mirless Diesel Engines are economical. For big cities, Steam-Engines, directly coupled to Pumps, are generally found to be very economical. These days, in many places, where the Steam-Plants get worn out, they are replaced with Electric-Motor-driven Centrifugal Pumps, purchasing electricity from the Electric-Supply Company, at special rates, to an appreciable saving in the capital cost for the purchase of the Plants, and in the repairing charges as well. But, certainly, in no circumstance, it is economical as compared to the

up-to-date directly-coupled Superheated Steam Plant in running expenses, since the Mechanical Efficiency of a Centrifugal Pump is low. Apart, in running a pumping machinery with electricity, a certain percentage is lost in generator, in the Motor, and in the Transmission Line; whereas the big steam-driven Pumping Engines, (Combined Engines and Pumps), of the latest designs, have been so designed that they have been working at 90% Mechanical Efficiency, although, at the latter case, more skilled staff have necessarily to be engaged. An Air-Compressor Plant is used for Tube Wells; but the Mechanical Efficiency of an Air-Compressor is as low as 30 to 35%; hence it is rather expensive to run. The only advantage is that the Air Pipe is laid in the Tube to force the water up and there is no other working part in the Tube Well.

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CHAPTER IX.

WATER SUPPLY TO SWIMMING BATHS

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WATER SUPPLY TO SWIMMING BATHS

This subject is one which has received of late much attention in India, because of the very large number of Swimming pools or baths erected in Bombay. Before explaining the present requirements and the method of treatment, let us first consider what the bath goers or users should expect in all public swimming pools or baths. The water should at all times be inviting in appearance of a clarity such that the smallest objects could be perceptible at the deepest point, in offencive to tender skins, of a suitable temperature at any point of the pool, and should not emit an aggressive smell of chlorine, and yet be sterile, because although not meant to be consumed, accidental absorption should have no ill effects. These conditions should apply equally to the private and public swimming pools. All public baths, prior 1902 in England, were made to run on the fill, and empty system. In this system, the pools were filled up with water, many times a week, and after a few days, the water was run to waste. The pools were then scrubbed to refill. The water of the swimming pools were not changed, as often as it should have been, and to do service for a number of days. This method was very unsatisfactory, because on the days when the water had been renewed, it was quite good in appearance and enjoyable. The private swimming pools of this type was constructed in the year 1941, by Mr. R. A. Dubash at plot No. 15 Worli. The water on the second or third day turn in appearance, odour and flavour, especially if the attendance had been fair on the first day. If water kept that length of time, it becomes totally unfit for bathing purposes, and becomes a happy breeding ground for bacteria, and aptly called as a mild sewage. Further disadvantages of this method, were that the quantity of water used to fill up the pools, were thrown down the drain with

the water, and the whole process started over again, directly fresh water was used. Night work also had to be resorted to empty, scrub down, and refill the pools, and blow into the water as much as could be raised in cold countries. This method is very good for a small make up, i. e. for the small private Swimming pools, such as the Swimming private pools at Worli Road, of Mr. R. A. Dubash, and in Worli Point in Jahaj Mahal of Sir Mahomed Yusuf of Navah Island.

In open air public Swimming pools, the conditions are different, in so far as the water being exposed to the Sun, air and light, a certain amount of auto-purification takes place ,and the turnover need not therefore be so frequent. Once every eight hours, the earlier in the smaller pools and every ten hours in larger pools, has been found satisfactory under normal conditions depending much upon the climate of the place, and on the class of patrons, size of the pool, and the popularity of the Swimming. For keeping the cost down, the financial side has also greatly improved. There has been saving in the cost of water, and the heating of the same, and the complete elimination of night work. What is more important, however, is the great increase of patrons of the baths. The former "Clean Water Day" patrons made use or the baths only once or twice a week, whereas "Clean Water Day" say a daily feature, which is much appreciated from the hygienic point of view. Another peculiar effect noticed is that bath Managers are always on view, whilst before they kept out of the way on the most days, so as not to hear the complaints. To our minds the installation of a purification plant will, in every case, not only reduce the expenditure, but increase the revenue, hence relief to the rates. We have heard a case of a very popular bath in London, having two pools, totalling approximately 1,50,000 gallons, the first class of 1,00,000 gallons used to be changed three times a week, and the second class of 50,000 gallons changed

twice a week. The weekly cost of this water at 1 shilling per 1,000 gallons was £20/-, the cost of the coal to heat 4,00,000 gallons was £10/-, overtime for the staff men £3/- making a total of £33/- a week excluding electric light, and other sundries. Since this bath has been fitted with purification plant, the water is always kept clean, and in perfect condition, at a cost of £4|- per week, for the cost of electric current and chemicals, £2|- for coal, and only £2|- for make up water, effecting a saving of £25|- a week, excluding increased consequent revenue. The method of treating bath water at first met with mainly because of the public baths in London are controlled by well-meaning, but sometimes impractical Councillors. There was much prejudice, and the pioneers had to tread ground very carefully. Glad on the face of results obtained, the early and fiercest opponents of the process have generally passed through the phases of hostility, tolerance and finally appreciation. The Regulations of the Ministry of Health insist that all the baths should be so fitted, and they also recommend that existing baths should be modernized with a suitable installation, therefore the successful purification and treatment of bath water is an established fact, and has come to stay.

We shall take an indoor Orphanage bath of Bombay, where orphans are mostly taken daily, say in relays. A close inspection would reveal fairly clean hands, face and knees, but the body and feet would be questionable. These orphan children are so keen to make most of their time at their disposal, that almost as soon as they have descended their clothes, they are in the water, without having first taken the precautions of paying a visit to lavatory or showers, when the latter are available. The difference of temperature, between that of bath water and the human body, also the pressure of water on the immersed body as per the principles of Archimedes has an effect that we must leave it to your imagination. This

coupled to the dirt loosened by the water, the exercise makes the water very similar to a mild sewage. By this, we mean a water containing much organic matter, and as such, a perfect nursery for the bacteria. The dye-from cheap costumes, is also a very noticeable source of trouble in the early season.

Now, we come to the present method used in England, and America. The water is drawn from the lowest point of the deep end of bath, and flows through the strainer (a box fitted with a coarse mesh cage or frame, which can be replaced easily by a spare one, on opening the guide-release cover) where the larger impurities, such as slips; water polo caps waddings; pieces of costumes and objects, accidently dropped or thrown in bath, are arrested. It is surprising the amount of impurities that collect, even on such course strainer gird, which should be changed daily, as the hairs etc, form a solid mat, impending the flow. From the strainer, the water is either fully aerated before filtration, or passed direct on to the filters, which should always be at least two in number, and work in parallel. Before the water arrives on the filters a very minute quantity of sulphate of alumina, and soda is injected, to form on the bed the jelly like substance which would coalesce the impurities in suspension, and prevent the same from working down into the lower levels of filter bed. Both these chemicals are dispensed and introduced in the water by means of a device, such as plunger pump, or by means of differential pressure, created by the passage of the main flow of water through a Venturi throat. Whichever device is adopted, it should be simple, adjustable, whilst in operation, and most accurate, since the injections of these chemicals is usually in the minute proportions of one grain of sulphate of alumina, and 1|2 grain of soda per gallon of water treated, and on this regular and correct injection will depend the performance of the plant.

Some may wonder why soda is added with sulphate of alumina. It is to provide the necessary carbonates for the reaction of the latter chemical and to form hydrate of alumina, which is the porous jelly or film. Some waters have been provided by nature with enough carbonates to be able to dispense with the soda, but if the same water is used over and over again, its natural carbonates will in time become exhausted. Carbonate of soda provides the defficiency. The water, suitably dosed with chemicals, arrives in the filters. The entry into the filter is so arranged, that the incoming water does not disturb the coating of jelly or film on the filter sand, through which it has to percolate to reach the collecting manifold at the lowest point. This manifold should be so arranged as to provide an even draw off from the whole surface. The sand or the filtering media should be of varying grades, starting from the fine at the top to fairly coarse over the collecting manifold, totalling at least three feet in depth. The rate at which the water percolates through the sand has led to much arguments, as one will realise that upon this rate, expressed in gallons per square foot of filtering area per hour, depends the size and number of filters to give a certain output, and finally the cost of installation. The Ministry of Health have made a strong recommendation that this rate should be about 200 gallons per square foot per hour, which comes to a downward penetration of six inches per minute. This is approximately double the rate usual in Water Works Rapid Filters for the drinking water. The method of cleaning the filtr sand bed is the same. The filtered water then flows to the aerator, which is a large container through which air is blown or induced. The object is to oxidise organic matter, in solution, and to get rid of foul gases, and give the water a sparkling appearance. Air is provided by air blower, an air compressor, or a device operating on the self induction principle. Immediately after aeration, water is passed through a tabular Calorifier to bring it back to

the required temperature of 72° to 74°. The water now requires its final treatment, viz Chlorination. It is introduced in the return pipe, and the amount of chlorine injected varies with the amount of organic matter present. The water is now in a fit state to be returned to the bath. The plant should operate the whole-time bathers use, or are likely to use the pools, and not to run only for short intervals as the difference in cost between remaining whole time and part time only, will not be appreciable. If an establishment has more than one pool, the filtration plant should be of such a size as to deal with the contents of all the pools in four hours only. We are afraid that until recently the real value of the aeration in Water Purification had been misunderstood or lost sight of. The Pioneers, whether by design or accident, had aeration before filtration, by means of an aeration situated in the open on the roof of the building. A none too pleasant smell from these aerators was quite noticeable. Personally, we are greatly in favour of imitating Nature's way of Auto-Purification.

The Willingdon Sports Club's Swimming Pool is the best Cosmopolitan Club in Bombay, situated at Mahalaxmi, opposite the Mahalaxmi Race Course, for its successful attempt to provide a large Swimming Pool of an up-to-date pattern for the use of its members. The swimming pool is 60 ft. long and 30 ft. wide, and has a capacity of 76,000, gallons. The depth of the water in the pool varies from 3 ft. 6 in. at the north end 7 ft. 6 in. at the south end with the maximum depth of 9 ft; 15 ft. from the deep end. As the site was a water logged area, the pool is constructed entirely of reinforced concrete. The pool is lined on the inside with the coloured vitrious tiles. The surroundings of the pool have been paved with chequered pattern cement tiles for the width of about ten feet on long side, and twenty feet on short side. The rest of the area is covered with lawn. At the Southern end, two diving boards, one metre and three metres high are

provided. The former rests on the raised platform and galvanised iron pipe stand, while for the latter, a diving stage is constructed of a reinforced concrete with cast *in situ* steps. One of the features of the pool is the under water lighting. Electric lights are fitted in six R. C. C. boxes, three on each side, attached to the sides of the pool. The six circular opening between the pool and the boxes are provided, at a depth of about three feet, with a powerful lenses fixed in watertight frames. When lit, they produce a scintillating effect at night. Water in this pool is always fresh and continuously circulated. Scum troughs have been constructed in R.C.C. and lined with tiles and terrazzo finish, at water level in the pool. These channels on both sides conduct the surplus water to the balancing tank of the filtration plant. From the tanks it is pumped into the filter, where it is purified, and whence it returns fresh and cool through the nozzles provided in the central channel at the bottom of the pool. A covered balancing tank of 10,000 gallons capacity is provided to maintain the water supply of the pool at its full capacity. An important adjunct is the dressing room block, consisting of a number of small cubicles for changing, shower baths and attendants rooms and machine room. There is a large open terrace over this block, where bathers can rest or take a sun-bath. The access to the terrace is by R. C. C. spiral stairs of a plain and artistic design. The exterior of the block as well as the spiral staircase, the diving stage, and the cascade have been finished with silver grey colour "crete" plaster, which gives a very pleasing effect to the pool, and its surroundings and the erection of colonades for high power electric lights all round the pool.

Before concluding, we would like to voice the suggestions, in general:

(1) Having been a swimmer in the school and college life and knowing one bath in Bombay all

the bathers should be asked to make use of lavatories before entering the water.

(2) A point worthy of consideration, in case of swimming baths, is to provide plenty of lavatory accommodation and in the most accessible place any part of the pool, i.e. half way between deep and shallow end, and the money spent for this, will surely appeal to people possessing even the smallest sense of decency, and the notices "as Spitting on floors etc; prohibited," may never be necessary.

(3) Success of the pool will depend on the good quality, and appearance of the Water, and this in return depends on the man at the wheel or man in charge.

(4) Water level should be the same as the deck level, but the coping, say 15 inches wide, should be raised to the height of the usual free board, to prevent any dirt, brought in by boots, being washed into the pool when the attendants swill the deck.

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CHAPTER X.

"VILLAGE WATER SUPPLIES"

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Pure Water To Drink For Small Communities

One of the greatest benefits conferred on humanity by the Sanitary Engineer is the provision of excellent water supplies. Most of the large towns and cities, like Hyderabad Deccan, Calcutta, Karachi, Mhow, Indore, etc., possess ample provision of pure domestic water, but the conditions in rural districts still leave much to be desired. This problem has been taken up very recently by the Congress Government of Bombay.

Once, we remember on 23rd Nov. 1937, Sir Firozkhan Noon, the then High Commissioner for India, speaking at a conference of the Royal Empire Society in London, on the subject of "Empire Development," said that the friends of India should attempt to raise India's standard of living, so that it would be more on a level with other parts of the Empire.

Improved Standard Of Living:—As regards water supply for instance, the standard in many large towns and cities in India, is probably as good as in the other parts of the Empire, but in rural districts, the conditions from a Sanitary Engineering and Health point of view, offer a very wide field for improvement. Where improvements are necessary in cities and large towns, they can afford to call in an adviser, like Sir M. Visveswaraya, as done by the Bombay Municipal Corporation on the proposed Bhiwpuri Water Supply schemes, to explore the possibilities of providing an improved supply; but villages in India, with a population of say 500 or 600 persons, are left each to follow the old customs, which are nowadays looked upon as dangerous. The villagers take their water from a shallow well, by lowering their vessels by means of a rope, and drawing them out again by

hand. These vessels are invariably clean, as observed by our naked eyes but germs on them are invisible. The rope and the vessel may appear to be harmless, but the germs on them contaminate the water, spreading disease and epidemics.

Village Water Supply:—The provincial Governments and States are now spending considerable sums of money on the improvement of Village Water supplies. It is stated that the Government of Mysore, for instance, have during the past 3 years, 1935 to 1938, provided 2,430 wells at a total cost of about Rs. 7,00,000, the average cost per well being about Rs. 290, and no arrangements have been provided for drawing water from these wells; so the old customary method will be followed. The Nizam Government has done well in this direction, and a special officer in charge of well sinking Dept., Capt. Leonard Munn, M.E. (Camborne), was appointed. The Government of Bombay has made provision for an expenditure of Rs. 10 lacs on Village Water Supplies during the year 1946-47, the object being to encourage self help and co-operation among the villagers. The scheme is to provide pucca wells, the average cost of which is not to exceed Rs. 500 out of which a Hand Pump complete with installation would cost about Rs. 120. It is intended that the villagers themselves will raise their own water by means of this hand pump provided in the Scheme. As regards quantity this is an improvement and it will be an improvement as regards quality provided the pump is always used, and the habit of lowering vessels in the wells is stopped or discarded. But, the fact that numbers of impatient villagers congregate at the wells makes it almost certan that they will resort to their dirty habits of dipping their vessels in the water, and the beneficial object is thus frustrated.

Thus, the health of the rural population is always a serious question for the Government and local

Authorities and Indian States, like Hyderabad States, **etc. In some places, where the only available source** of supply are shallow wells and the condition of such wells is not satisfactory, and requires attention to see that the well itself is cleaned, that the masonry lining or steeming is sound and carried up above ground level to a height of at least 2'6" and if possible to have a paved area, say about 5 ft. wide, surrounding the well with a drain to take spilt water therefrom away from the well. The ground surrounding the well, for a distance of 100 yards at least from the well should be kept in sanitary condition, as per remarks of Dr. Parker in his book on "Hygiene and Public Health." The shallow wells are always looked upon as a dangerous source of supply from health point of view, and it is stated by Dr. R.J.M. Buchanan, in his book "Husband's Forensic Medicine, Toxicology & Public Health," that a large sanitary zone around the well will greatly help to lessen the danger. Unless the dirty habit of the villagers dipping their vessels in the well water, contaminating the source of supply is stopped, there can be no real improvement, and realisation of the full value of money spent on providing or improving wells will be realised. How can this be effected? The answer is by avoiding the necessity for the villagers to take water at the well itself. This can only be done by providing a system of distribution by piping, as is done in places, where the standard of living is considered high. A piped distribution has become a necessity, as one of the improved standards of living in the vllages. The "American Abyssinian" or "Tube wells" are useful in supplying water to an army. The tube wells, however, failed in Asiatic wars from their becoming clogged with sand.

.*Distribution System:*—This suggestion of a piped distribution system immediately brings to mind power pumps, engines and skilled labour to run the plant because before the well water can be distributed, it must be raised sufficiently to give a

satisfactory discharge from the pipes. In villages and small towns pumping plant is impossible, on account of the expense of providing and working the plant. The means of raising water from the well must be cheap in outlay and the working must be simple and reliable. Water from the well would be delivered into an elevated storage tank, suitably placed so that water can be distributed by means of service piping, to the houses direct or to central public standpipes, this will be required apart from the means of raising the water.

For example, Ichalkaranji State Water Works has found it necessary to duplicate the pumping plant in the Pumping Station Tower to prevent any discontinuance of the water supply. The supply and erection of new engine and new pump base was carried out by M/s. Turner Hoare & Co. Ltd., Bombay, who supplied and erected the original engine and deep well pump in the year 1926. The engines are of 24 or 28 B.H.P. Petter two-stroke cycle, cold starting type with direct injection of fuel oil. There are, of course, no valves, valve operating gear or other complicated devices. The engines are directly coupled by a centrifugal clutch to the intermediate gear shafts of the deep well pump manufactured by Lee Howel & Co. Ltd., of Tipton, the capacity being 15,000 gallons of water per hour, and the daily delivery about 100,000 gallons. Water is pumped direct from the tower situated on the bank of the river Panchganga to a reservoir in the town, 1¼ mile away, from where it is distributed by gravity to cisterns located in different parts of the town.

There are other suitable means of raising water from a well so far as the Village Water Supply is concerned, besides pumping. They may not be as efficient as a pumping installation when compared in terms of foot pound of work done, but they are cheap, simple and reliable and such as are well understood by the villagers.

The Charsa:—Agriculturist is a poor man in that he is wanting in material riches. He has to take considerable quantities of water for the ground to irrigate his crops, and because of his poverty, he has to do this in a cheap, simple and reliable manner. He does it by means of 'Charsa' or Mot and his bullocks. This has been his method from time immemorial, and the fact that it has survived to the present day proves its suitability. Even with the more modern mechanical methods available, the Charsa or Mot is satisfactory even today, upto a point; for we find animal power as well as mechanical power being used in the same vicinity, the choice depending principally on the quantity of water to be raised. One charsa is certainly the cheapest and best way of raising water upto 12,000 gallons daily to a height of 100 ft.

It is, therefore, suggested that to be effective, the improvement to village water supplies lies in providing:—(1) a suitable source of supply, (2) a means, whereby the source is kept from contamination.

From the foregoing remarks, it is seen that Government and States are taking steps to cope in the former, and in certain cases, by providing hand pumps, they are taking up the latter, but it is doubtful whether the hand pump is the best way of dealing with this. The Charsa or Mot would certainly appear to be preferable, for it has been used continuously during the past over 70 years at the numerous stations on G. I. P. and other railways, and today it is, as it always has been, the cheapest and most reliable means of raising small quantities of water, where a piped distribution is required, e.g., at auxilary watering station, and some of this type have been replaced by power pumping sets, because the advent of larger tenders made longer engine runs possible, and to supply larger quantities, beyond the capacity of the Charsa.

A typical type of Charsa installation is at Saugor on the Bina-Katni section of Rly., 654 miles from Bombay, and the cantonment situated in Central Provinces, 1,940 ft. above sea level. Saugor is built on the north west border of a fine lake, nearly a mile abroad, with a Military Equitation School. It is illustrated as under:—The well is 15' in diameter, and the bottom is 82 ft., below the coping of steeming of the well. The frame work, mounted on the steeming is made of scrap rails, and the upper pulley on which the lifting chain run is 23' above the coping of the well. At a height of 18 ft. above the coping, there is a platform made of old sleepers, 3' 9" square on which is placed a mild steel plate tank, 1 ft. high into which the Charsa discharges its contents. From this small tank a 3" dia. pipe conveys the water to a high service storage tank, holding about a day's supply, and situated at the station, 120 yards away from the well, whence the water is distributed by service piping. The Charsa or the mot bag is made of leather and it is raised by means of a ¾" chain passing over the upper pulley, then down to the guide pulley at the base, of the frame, and the free end is attached to the yoke of a pair of bullocks.

A man guides the bullocks backwards, and forwards along the earth ramp, which is 122 ft, long with a slope of 1 in 14. The quantity of the water raised in the bag at each lift is 26 galls., and the total daily quantity raised is about 12,500 gallons. The working of the charsa is let out to a local man on contract say at Rs. 30 or Rs. 35 a month, and to provide his own bullocks. It is also learnt that the cost to the railway excluding interest and depreciation on the well and Charsa is about 1½ annas per 1000 galls. The water is supplied to engines and to about 180 railway employees, and their families, and also for about 400 to 500 of the travelling public. It is possible that many villages would be able to work the Charsa at a cheaper rate than this by self help and co-operation. Take for example, say thirty

owners of buffaloes in a village, and each one were to make himself responsible for working the Charsa for one day during the month for the benefit of the village and the cost to the community would be negligible. The hand pumping is the most expensive method, while the Charsa is the cheapest for quantities of this nature. Other advantages of the Charsa are there is nothing to go out of order, which cannot be repaired in the villages and also a stand-by set is not necessary as a spare bullock can always be obtained at short notice.

In this mechanical age there are some conditions which lend themselves to old fashioned methods. This is one. For raising upto about 12,000 galls. of water daily to a height of anything upto 100 ft. the Charsa is the cheapest method, and every villager will understand and its inexpensiveness brings a piped supply, and so a purer supply within the reach of all classes. Co-operation to prevent waste would be necessary if a piped supply is adopted. In conclusion, the Village water supply from the post-war reconstruction schemes on these lines means that the standard of living in the villages and Districts of India can be raised at very small cost, and without interference to present arrangements. This would be an enormous contribution towards improving the health of the whole country. C. P. Governor, Mr. Mangaldas Pakvasa, has told the press representatives that more attention must be given for the improvement of villages first in the Post War Reconstruction Schemes.

Waste of water notice to the public:—The following hints or tap tips for saving precious water:— .

(1) See that your taps are never let running.

(2) Avoid washing vegetables, hands, cleaning your teeth, under a running tap.

(3) Cut your baths down, and use only 5" of water.

(4) Have all leaky taps and faulty fittings repaired.

The first two of these hints are concerned with taps that are left running, during ablutionary and cullinery operations. Astonishing volumes of water can be consumed by these means.

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CHAPTER XI.

"SOME OF THE PROBLEMS CONNECTED WITH VILLAGE WATER FILTRATION"

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"SOME OF THE PROBLEMS CONNECTED WITH VILLAGE WATER FILTRATION"

To provide an ample supply of clear water to drink at all villages in the post-war reconstruction schemes, is one of the objects of the Engineering Department of Provincial Government.

The data required usually for Headwork, are two in number, and always to be taken into consideration before going for a Water Supply Scheme, small or large.

(1) The population of the place i.e. the present and the ultimate population study should be made with predictions for the next 25 years, as per remarks of Water Engineer, Mr. W. D. Hurst, M.I.C.E., in his paper on "Design of Water System."

(2) The rate of supply i.e. say 15 to 20 gallons and for sewerage 25 gallons.

A perennial river close to a village is, of course, the ideal source of supply. Practically all Indian rivers have a flow of clear water during the major portion of the year, but immediately the monsoon breaks, the water shed is washed clean of all dust, and other light matter that has collected thereon, during the dry season, and by the time the rain water reaches the rivers, it is heavily charged with particles of matter varying in size. The heavier particles are deposited on the river bed, while the lighter ones are carried along by the stream, the lightest remaining in suspension in the water for a very long time. The velocity of water flow through alluvial tracts, when traversing the plains, the banks are frequently of a friable nature, and during floods considerable portions are cut away by the current, and the particles, being fine and light, add greatly to the amount of solid matter carried along by the stream.

The water is discoloured by these particles, and generally ranges from a cloudy or pale yellow to muddy or deep brown colour. Generally, the pale yellow periods occur for a short time at the beginning and end of the monsoon, while the brown colour remains during almost the whole of the rainy season, irrespective of the flood level. Water of this nature is objectionable both from the point of view of domestic as well as industrial supplies. Even a cloudy appearance is objectionable in drinking water, and solids in suspension will give rise to priming and foaming in boilers. Such water should always, as a rule, be filtered.

To ascertain whether filtration of river water is necessary in order to make it suitable for use, daily observations should be taken over a period of 6 to 12 months. For example, on the G. I. P. Rly., as told by Mr. G. C. Minnith, M.I.C.E., the then Sanitary Engineer to G. I. P. Rly. in his lecture in 1935 the two conditions which are particularly noted are the colour of the matter, and the level of the surface. The colour is classified under four heads:—

Clear; cloudy; yellow and brown, and samples of each of these colours are kept in clean winchester bottles, during the period of test for comparison and reference. The water levels are plotted on a graph paper with the dates as abscissas, and the water level as ordinates, and on this is also shown the colour of the water. This diagram shows at a glance whether the water need be filtered, for if there are only isolated days on which the water is yellow or brown, and if these are not of frequent occurrence filtering may not be justified, but if as often happens, the yellow and brown periods extend over a considerable portion of the year, then filtration will be definitely required.

Type of Filter:—

Where the water is of such a nature as to require filtration, it is obvious that if possible, this should be

effected before the water enters the pipes and pumps, and this can be done either by means of an Infiltration Gallery or a sump well built in the river bed. The choice depends on the nature of the river, and of the river bed. If the river is perennial with an impervious bed, an infiltration gallery in the form of a gravity filter would be adopted, but where the flow ceases in the dry season and the bed of water is bearing sand or alluvium, then an infiltration gallery designed to permit percolation through the sides as well as through the top or alternatively a sump well would be chosen, Either form of gallery or the sump well would be built as close to the bank as possible.

Infiltration gallery consists of the concrete or cast iron pipes with very small holes or bores all round, and throughout the entire length of the pipe, and the pipes of porous material and laid on the bank of a river or sometimes inside the river bed. Each one is connected with the wells dug, and is afterwards pumped by some convenient means, and afterwards it is purified and supplied. This is also one of the source of water supply coming into prominence since 30 to 40 years. There is no difference between the infiltration gallery and supply wells used in Ahmedabad for example. The supply wells are used, when the river is shifting or changing its course in flat countries, generally like Ahmedabad, and the remedy for this is, piling.

An infiltration gallery would be adopted where the depth of the water bearing material in the bed is less than 8 ft. Broadly speaking, this is a gallery or chamber about 3 ft. wide by 3 ft. deep, having a cement concrete floor, dry rubble masonry sides through which, either by the dry joints or by pipes built into the masonry, the subsoil water can flow freely into the gallery, and a covering of stone slabs or old rails having open joints, which permit further ingress of water into the gallery. The length must be such that more than the required quantity of water will enter the gallery. On top of the covering, a

layer of gravel is laid, and above this, a filling should be such that the rate of inflow will not exceed 3 ft. per hour. This type of infiltration gallery is used in India, and particularly on G. I. P. Rly. at Shehgaon, Dhamangaon, Pulgaon, and other places, and all have worked very satisfactorily without any attention for many years.

The infiltration gallery size can be increased, where the river is perennial with an impervious bed, like the river Bhima at Pomalwadi (a place of 95 miles away on Southeast of G. I. P. Rly. lines from Bombay) the side walls of this gallery are continued up above the open jointed covering to form a chamber, which holds the filtering sand, thus only the top area is available, and the size of the gallery is accordingly increased. This gallery (when visited in the year) 1937) has worked continuously and without attention, since it was built in the year 1916.

The most important feature in the design is the filtration area, which is dependent on two factors:—(a) Quantity of water required to the filtered (b) Rate of percolation through the sand, which will be used. The outside information on the subject of percolation is extremely scanty and vague, but from information available on Indian Railway records, a rate of 5 gallons per square foot per hour is safe for ordinary washed river sand with a head of 2 ft. or more of water. This leaves a margin for a certain amount of clogging of the filter, so that cleaning will be unnecessary for many years.

The pressure filters are used to avoid generally double pumping, whereas open pressure filters are used, when double pumping is required. The mechanical filters, such as, Jewells, Paterson, Candy, Boby's and Bells, and the principle underlying in connection with the Mechanical filters are:—(1) Coagulation tank and (3) Mixing trough, when algae is present in water, the best thing is to use Mechanical filters (used at Kalyan).

A sump well is used, where the depth of the water bearing material in the river bed is more than 8 ft. A convenient form of well is circular in plan with walls and cover of R. C. C. and angle iron cutting edge mounted on a curb made of steel sections. After the well has been sunk to its final portion, a layer of boulders or rubbles about 18" thick should be laid to prevent movement of the sandy or friable bottom of the well, because the bottom of the well is the percolation area. The basis for design is that the velocity of the water percolating into the well shall not be greater than 3 ft. per hour, and from this, the area of the well is obtained. The example of the sump well of this description is at Mahol (a railway station between Kurduwadi and Sholapur) on G. I. P. Rly. line. It was built in the sandy bed of the Seena river in 1928, and since then it is working satisfactorily without much attention.

Whether an infiltration gallery or sump well is used, a duct of such a size that it can be cleaned easily will have to be provided to lead the filtered water into the pump well on the river bank. If the distance is small, a pipe will suffice, but where a pipe is unsuitable, a masonry duct line, say 3 ft. wide by 4' 6" high, will have to be built. The floor of the Gallery, and the duct line should have a slope of 1 in 80 towards the duct outlet, which will be a chamber for the clear water in which the pump suction pipe is installed. A duplicate suction pipe drawing direct from the river must be provided for use in case of the sump well or gallery is out of action. In case the efficiency of the filter is reduced by the surrounding soil or sand becoming clogged through over pumping, the remedy is to receive the clogged material and replace it with clean material.

If the supply is from the lake or reservoir, filtration would be effected by either rapid sand filter or a pressure filter should be introduced in the rising main. There is something to be said both for and against all these methods; the infiltration gallery and

sump well need not be inspected throughout the year, whereas the rapid sand filters and pressure filters require daily attention, and are thus a great deal more expensive to maintain.

For a moderate sized village, say 400 gallons per hour, and infiltration gallery would have filtering area of 800 sq. ft. at least, and the cost would be in the neighbourhood of Rs. 2,500/- (pre-war price) approximately, and a suitable sump well would have a percolation area of 250 sq. ft. to keep the velocity of inflow at a safe rate, and the cost would be about Rs. 10,000/- say. A vertical pressure filter of this capacity would be about 7 ft. in diameter, and would cost Rs. 5,000/- say installed complete.

Under the suitable conditions, the infiltration gallery is the most economical method of dealing with muddy river water. A gallery 80 ft. long by 10 ft. wide has been adopted at the new pumping installation on Ken river at Banda on the Jhansi-Manikpur, north-east line of the G.I.P. Rly. This work was taken in hand in the year as told, 1936 or 1937, and since then working nicely.

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CHAPTER XII

USEFUL DATA FOR WATER ENGINEERS

USEFUL INFORMATION FOR HYDRAULIC CALCULATIONS

1 Gallon (Imperial) of water	=	277·46 cubic inches.
	=	·16 cubic feet.
	=	10 lbs. in weight.
	=	4·546 litres.
	=	1·2 U.S. gallons.
1 Cubic Foot of water	=	62·3 lbs. in weight.
	=	6·23 gallons (Imperial).
	=	7·48 U.S. gallons.
	=	28·31 litres.
Atmosphere	=	14·7 lbs. per sq. inch.
	=	1·033 kilos per sq. cm.
	=	33·95 ft. head of water.
	=	760 mms. of mercury.
	=	29·92 inches of mercury.
Column of water 1 ft. high.	=	Pressure of ·4325 lbs. per sq. inch.
	=	·885 inches of mercury.
1 Cubic Metre of water.	=	220 gallons (Imperial).
	=	35·315 cubic ft.
	=	1000 litres.
	=	1000 kilogram weight.
	=	1 ton in weight (approx.)

1 Cusec (cubic ft. per sec.)	=	374·1 gallons per min.
Head in ft. of water	=	lbs. per sq. in $\times$ 2·312.
1 Horse Power.	=	33000 ft. lbs. per minute.
	=	·746 kilowatt.
1 *Inch of* Water on an acre.	=	100 tons (approx.).
1 Inch Column of Mercury	=	1·13 ft. head of water.
	=	·49 lbs. per sq. inch.
	=	·344 metres of water.
1 *Kilogram.* per square *centimetre.*	=	14·223 lbs. per sq. inch.
1 Lb. per square in.	=	2·312 ft. head of water.
	=	2·035 inches of mercury.
	=	·7047 metres of water.
1 U. S. Gallon of water	=	231 cubic inches.
	=	·833 Imperial gallons.
	=	3·773 litres.

1 Ton of Crude Petroleum. = 275 gallons (approx.).

1 Cubic Foot of sea water. = 64. lbs. in weight.

FORMULAE

A = Area of pipe in square inches.
C = Cubic feet per min.
D = Internal diameter of pipe in inches.
E = Efficiency per cent.
G = Gallons per min.
H = Total pump head in feet.
L = Length of pipe in yards.
P = Wt. of water per min. in lbs.

Water Horse Power (W.H.P.) $= \dfrac{P \times H}{33000} = \dfrac{G \times H}{3300} = \dfrac{C \times H}{529}$

Brake Horse Power (B.H.P.)—power absorbed by pump.

$$B.H.P. = \frac{W.H.P. \times 100}{E.}$$

Velocity of wate in ft. per second $= \dfrac{G}{2{\cdot}6 \times A.} = \dfrac{G}{2{\cdot}02 \times D^2}$

Wt. of water in a pipe in lbs. $D^2 \times L^2$

Capacity of Pipes in gallons per foot $= \dfrac{D^2}{29{\cdot}5}$

Doubling the diameter of a pipe or cylinder increases in capacity four times or reduces the velocity in the pipe to one quarter.

TEMPERATURE CONVERSION

F = Degrees Fahrenheit,
C = Degrees Centigrade

$$F = \frac{9\,C}{5} + 32,$$

$$C = \frac{5\,(F - 32)}{9}$$

Absolute Zero = —273° C = —460° F.

Head in feet of water = Pressure in lbs. per sq. in. $\times 2{\cdot}13$

Theoretical Velocity of Discharge in ft. per sec., $V=\sqrt{2gh}$, where $g=32{\cdot}2$ and h = head of water in ft.

Discharge through nozzle = C.a.v. = C.a. $\sqrt{2gh}$ cu. ft. per sec.

where a = Area of nozzle in sq. ft.
and C = Cofficient for nozzle.
For smooth taper nozzle C = ·94.

ELECTRICAL DATA

Speed of A.C. Motors in R.P.M. $= \dfrac{\text{No. of cycles} \times 60}{\text{No. of pairs of poles}}$

This makes no allowance for slip, which amounts to approx. 4 per cent. If electric current is A amperes(per phase) and voltage between phases V.

For Direct Current.

$$\text{E.H.P.} = \frac{V \times A}{746}$$

$$\text{K.W.} = \text{K.V.A.} = \frac{V \times A}{1000}$$

For Single Phase A.C.

$$\text{E.H.P.} = \frac{V\ A \cos \alpha}{746}$$ where $\cos \alpha$ is Power Factor.

$$\text{K.W.} = \frac{V\ A \cos \alpha}{1000}$$

$$\text{K.V.A.} = \frac{V \times A \cos \alpha}{1000}$$

For 3-Phase A.C.

$$\text{E.H.P.} = \frac{1{\cdot}732 \text{ V A } \cos \phi}{746}$$

$$\text{K.W} = \frac{1{\cdot}732 \text{ V A } \cos \phi}{1000}$$

$$\text{K.V.A.} = \frac{1{\cdot}732 \text{ V A}}{1000}$$

BELT DRIVES

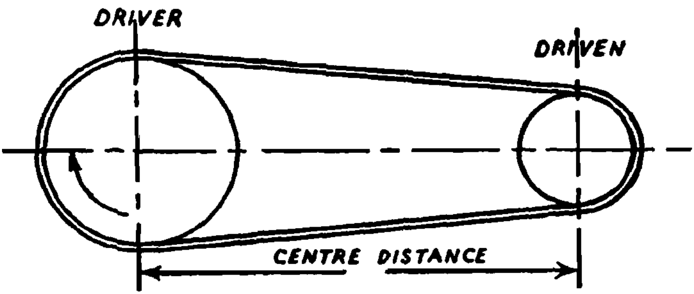


Fig. 27.

$$\text{R. P. M. of Driven Pulley} = \frac{\text{Dia. of Driver x R.P.M. of driver}}{\text{Dia. of Driven.}}$$

An allowance of approx. 2 per cent. should be made for slip. If possible, slack side of belt should be on top. Maximum belt speed should not exceed about 3,000 feet per minute.

TO FIND THE LENGTH OF A BELT.

R = radius of large pulley. r = radius of small pulley
C = Centre distance of pulleys. L = Total length of belt

Open Belt:— $L = 3{\cdot}14\,(R+r) + 2\sqrt{C^2 + (R \times r)^2}$

For Equal Pulleys:- $L = 3{\cdot}14\,(R+r) + 2\,C.$

For Crossed Belt:— $L = 3{\cdot}14\,(R+r) + 2\sqrt{C^2 + (R \times r)^2}$

Steam and Air.—1 Cubic foot of Air at 14.7 lbs. per sq. in. and 62°F weighs .076 lbs. 357 Cubic feet of a perfect gas at atmospheric pressure and 32°F. weighs its molecular weight in lbs.
(Approx. molecular weights :—O_2 32, H_2 2, N_2 28, CO_2 44, H_2O 18,).

Specific heat of air (at constant pressure) = .238
Adiabatic index for air (and other diatomic gases) =141.

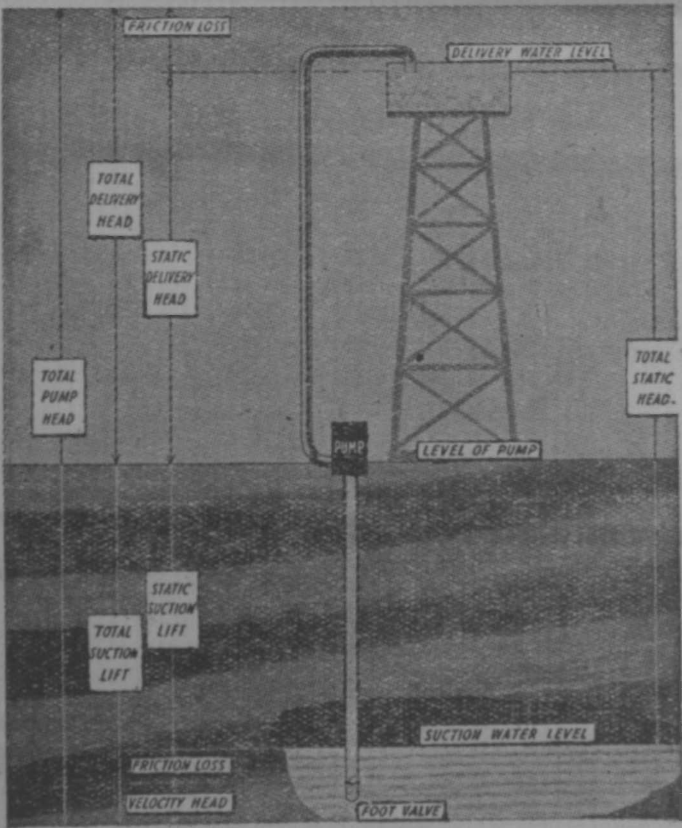
Mean Specific Heat of Superheated Steam at 200 lbs./sq. in. abs. between saturation temperature and 500°F. = .57.

Manual Power.—One strong man can work at an average rate of 2,800 foot-pounds per min. (.085 H.P.), based on a working day of 8 hours.

A man can work a Lever Handle for a reasonable time against a moderate lift at 30 strokes per minute or a Winch Handle at 30 revs. per minute.

The mistake should not be made of selecting a hand pump of large size to be worked with a heavy lift with the result that it is almost impossible for even a strong man to work it for more than a few minutes.

NOTES ON PUMPS
PUMPING TERMINOLOGY



A diagram illustrating graphically the principal terms used in pumping

3

Fig. 28 illustrates graphically the principal terms used in pumping.

Total Static Head is the vertical height through which the liquid has to be raised measured from the

suction level to the delivery water level or the highest point of delivery.

Total Pump Head is the total static head plus friction loss and velocity head, and represents the total head from which the power exerted by the pump must be calculated.

Velocity Head represents the head in feet due to the velocity of the water in the pipes as calculated from the fundamental formula $\frac{V^2}{2g}$ where V is the velocity of water in the pipe in feet per second and $g = 32.2$. In the majority of cases it is extremely small and can be neglected.

Friction Loss is the loss in energy due to friction set up between the water and the inside surface of the pipe. It varies approximately as the square of velocity of water in the pipe and depends also upon the roughness of the surface of the pipe, and varies directly as the length of the pipe. Other factors which increase friction loss are sudden changes in direction, due to sharp bends, sudden changes in diameter, and obstructions in pipes as created by certain types of valves. Tables of losses due to friction are given in Tables "19" and 20, pages 262 and 264 to which reference should be made.

Total Suction Lift. The pressure of the atmosphere will support a column of water approximately 34 feet high, and it therefore follows that the maximum height to which water can be theoretically lifted by creating a perfect vacuum in the suction pipe is 34 ft. It is not desirable to recommend that any pump be used for a greater total suction lift than 25 feet, and in the case of certain types of pump this value should be decreased. It is necessary in every case that the suction pipe be perfectly air tight, particular attention being paid to all joints, and it is recommended that a foot valve and strainer be fitted

to the bottom of the suciton pipe. When the water is more than 25 feet below ground level, a pump of the "deep well" type must be utilised.

The above notes on suction lift apply to cold water only. For liquids other than water, suction lift is affected by viscosity and specific gravity of the liquid. For pumping hot liquids and in particular hot water, as in boiler-feed pumping where the feed water temperature is high, the vapour given off by the liquid counteracts the atmospheric pressure on the surface of the liquid.

The following table gives the suction lift and head for water at various temperatures:—

Temperature °F.	Maximum Suction Lift in feet	Temperature °F.	Head on Suction Valve in feet
130	10	190	5
150	7	200	10
170	2	210	15
175	0	220	22

Atmospheric pressure varies with altitude and the following table gives the maximum total suction lift which can be obtained at various altitudes:—

Altitude	Barometric Pressure in lbs. per sq. in.	Equivalent Head of Water in feet.	Maximum Total Suction lift of pump in feet.
Sea Level	14·7	33.95	25
¼ mile (1,320 ft.) above sea level.	14·02	32 38	23
½ mile (2,640 ft.) ,, ,, ,,	13·33	30·79	22
¾ mile (3,969 ft.) ,, ,, ,,	12·66	29·24	21
1 mile (5,280 ft.) ,, ,, ,,	12 02	27·76	20
1¼ miles (6,600 ft.) ,, ,, ,,	11·42	26·38	19
1½ miles (7,920 ft.) ,, ,, ,,	10 88	25·13	18
2 miles (10,560 ft.) ,, ,, ,,	9·88	22·82	16

TABLE 19.
FRICTION LOSS
For Fittings in Equivalent Lengths of Straight Pipes (in feet)

Size of Pipes in inches	Velocity Head for Ordinary Pipe Entry	Velocity Head for Bell-Mouthed Entry	Bend	Foot Valve	Retaining Valve	Delivery Valve Full Open	Strainer	Tees and Elbows
¾	3·3	2·1	2·0	·6	·8	·6	·2	2·1
1	4·5	2·7	2·5	·8	1·0	·8	·3	2·7
1½	7·1	4·3	3 7	1·2	1·6	1·2	·5	4·3
2	9·8	5·9	5·0	1·7	2·2	1·7	·7	5·9
2½	12·6	7·6	6·4	2·1	2·8	2·1	·9	7·6
3	15·6	9·4	8·0	2·6	3·5	2·6	1·0	9·4
4	21	13	10·7	3.6	4·7	3·6	1·4	13
5	28	17	14·0	4·7	6·1	4·7	1·9	17
6	35	21	17·3	5·8	7·6	5·8	2·3	21

TABLE 20.
Equivalent lbs. per sq. in. for Heads of Water and Theoretical Velocity due to Head

Pressure in lbs. per sq. inch	Head of Water in feet	Theoretical Velocity of Discharge in feet per sec.	Pressure in lbs. per sq. inch	Head of Water in feet	Theoretical Velocity of Discharge in feet per sec.
10	23·1	38·6	85	196·3	112·5
15	34·6	47·25	90	207·9	115·8
20	46·2	54·55	95	219·4	119·0
25	57·7	61·0	100	230·9	122·0
30	69·3	66·86	105	242·4	125·0
35	80·8	72·2	110	254·0	128·0
40	92·4	77·2	115	265·5	130·9
45	103·9	81·8	120	277·1	133·7
50	115·5	86·25	125	288·6	136·4
55	127·0	90·4	130	300·2	139·1
60	138·6	94·5	135	311·7	141·8
65	150·1	98·3	140	323·3	144·3
70	161·7	102·1	150	346·4	149·5
75	173·2	105·7	175	404·1	161·4
80	184·8	109·1	200	461·9	172·6

TABLE 21.

SATURATED STEAM

Abs. Press Lbs. per sq. in.	Temperature °F.	Total Heat B. Th. U.	Volume of 1 lb. in cubic ft.	Abs. Press. Lbs. per sq. in.	Temperature °F.	Total Heat B. Th. U.	Volume of 1 lb. in cubic ft.
·3	65	1083	1030	100	328	1191	4·45
·5	79·5	1092	640·5	150	358	1200	3·04
·8	94·3	1098	411	190	378	1204	2·435
1·0	101·7	1102	333	215	388	1207	2·167
5·0	162·3	1130	73·4	240	397·6	1209	1·954
14·7	212	1150	26·8	265	406·4	1210·8	1·778
50	281	1176	8·52	290	414·6	1212·5	1·634

Suction & Delivery Pipes.—Suction pipes should never be of less diameter than those of delivery pipes. If smaller suction pipes are used it will result in the pump not properly filling, and if smaller delivery pipes are used it will create additional friction due to increased velocity of water in the pipe and consequently the power required to drive the pump will be increased.

Great care should be taken to ensure that suction pipes are perfectly air tight, and suction pipes should be arranged so that air traps are avoided, as these seriously interfere with the pump filing See Figs. 29, 30, 31 on page 267.

Foot Valves and Strainers.—A foot valve is advisable when the suction pipe is of large diameter or more than 10 feet in length.

A strainer should be fitted to the inlet of the suction pipe whenever the liquid contains solids in suspension whether of large size or in the form of grit. If no strainer is necessary it is advantageous to have a bell-mouth entry to the suction pipe, thus allowing the free entry of water and ensuring a full pipe without throttling the flow of water.

Retaining Valve.—A retaining valve should be fitted above the discharge valve when the head on the pump exceeds about 200 feet or when the delivery pipe is 200 feet long or more. This valve retains water in the delivery pipe when the pump is stopped and enables the pump to be primed by exhausting air in pump and suction pipe, and also prevents damage to pump through water hammer, caused by suddenly stopping the pump.

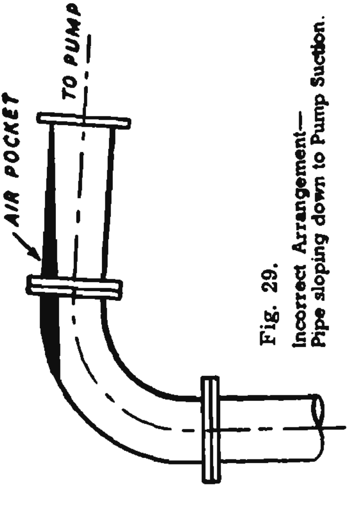


Fig. 29.
Incorrect Arrangement—
Pipe sloping down to Pump Suction.

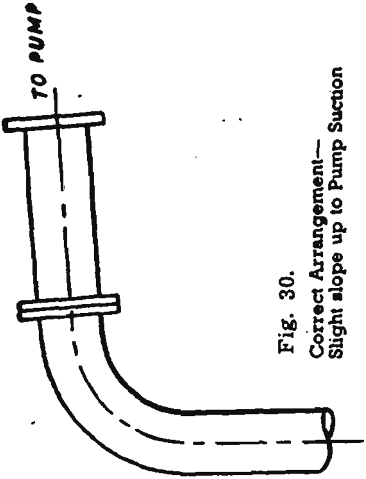


Fig. 30.
Correct Arrangement—
Slight slope up to Pump Suction

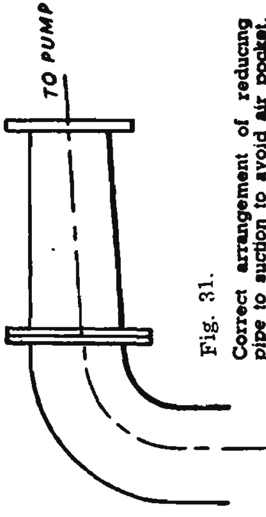


Fig. 31.
Correct arrangement of reducing pipe to suction to avoid air pocket.

INFORMATION REQUIRED WITH ENQUIRIES

In favouring pump manufacturers with orders or enquiries, customers are requested to send such of the following information as applies to the conditions under which the pump has to work.

(1) Number of gallons per hour.

(2) Liquid to be pumped. State if gritty, salt or corrosive.

If other than water, state composition and viscosity, if possible. Give as much information as possible under this heading, as it may affect the materials and general design of pump or valves.

(3) Temperature of liquid to be pumped.

(4) Details of suction lift and delivery head on pump.

Length of pipes, number of valves and bends should be stated.

If pipes are already installed, diameter should be given.

(5) State power intended to drive pump:

If manual, state if one or two men available.

If steam, give steam pressure available, quantity of steam temperature of superheat if superheated.

If engine, state power and R.P.M.

If belt, state diameter or driving pulley.

If electric motor state voltage and type of electric current (A.C. or D.C.), and if A.C., state phase and periodicity.

If compressed air, state pressure and quantity of air available.

The approximate heights to which a steam or air operated pump will deliver, are based on the steam or air pressure at the Pump Cylinder. If the boiler or compressor is a distance away larger pipes should be used and in the case of steam a Steam Trap.

If economy in fuel is an important consideration the Stèam Pipes and Cylinder should be lagged.

Gun metal linings, etc., are strongly recommended in cases where the pumps are only for occasional use.

CONVERSION TABLES.

Inches — Feet

Fractions of an inch.	Decimals of an inch.	Decimals of a foot.
$\frac{1}{16}$	·0625	·00521
$\frac{1}{8}$	·125	·01042
$\frac{1}{4}$	·25	·02083
$\frac{3}{8}$	·375	·03125
$\frac{1}{2}$	·5	·04167
$\frac{3}{4}$	·75	·0625
1	1·00	·08333

Inches.	Feet.
2	·1667
3	·25
4	·3333
5	·4167
6	·5
7	·5833
8	·6666

GALLONS—LITRES

True Gallons.	Litres.
1	4·5457
2	9·0914
3	13·6370
4	18·1827
5	22·7284
6	27 2741
7	31·8198
8	36·3654
9	40·9112

Litres.	True Gallons.
1	·22
2	·44
3	·66
4	·88
5	1·1
6	1·32
7	1·54
8	1·76
9	1·98

CUBIC FEET—GALLONS

Cubic Feet.	True Gallons.
1	6·228
2	12·456
3	18·684
4	24·912
5	31·140
6	37·368
7	43·596
8	49·824
9	56·052

Gallons.	Cubic Feet.
1	·16057
2	·32114
3	·48171
4	·64228
5	·80285
6	·96342
7	1·12399
8	1·28456
9	1·44513

CUBIC FEET PER SECOND—GALLONS PER HOUR

Cubic Feet per second.	Gallons per hour.
1	22,420
2	44,840
3	67,260
4	89,680
5	112,100
6	134 520
7	156,940
8	179,360
9	201,780

Gallons per hour.	Cubic Feet per second
1000	·04457
2000	·0892
3000	·1338
4000	·1784
5000	·2230
6000	·2676
7000	·3122
8000	·3568
9000	·4014

CUBIC FEET PER MINUTE—GALLONS PER HOUR

Cubic Feet per minute.	Gallons p r hour.
1	373·7
2	747·4
3	1121·1
4	1494·8
5	1868·5
6	2242·2
7	2615·9
8	2989·6
9	3363·3

Gallons per hour.	Cubic Feet per minute.
1000	2·6762
2000	5·3524
3000	8·0286
4000	10·7048
5000	13·3810
6000	16·0572
7000	18·7334
8000	21·4096
9000	24·0858

FEET HEAD—LBS. PER SQ. INCH

Feet Head.	Lbs. per Square Inch.	Lbs. per Square Inch.	Feet Head.
1	·4325	1	2 312
2	·865	2	4·624
3	1·2975	3	6·936
4	1·73	4	9·248
5	2·1625	5	11·560
6	2·596	6	13·872
7	3·0275	7	16·184
8	3·46	8	18·496
9	3·8925	9	20·808

FREE DISCHARGE OF WATER THROUGH AN ORIFICE.

H = height from centre of orifice to surface of water in feet.
V = velocity of issuing water in feet per second.
A = area of orifice in square feet.
a = area of orifice in square inches.
Q = discharge in cubic feet per second.
m = co-efficient depending on orifice.

$$V = m\sqrt{2gH} \text{ feet per sec.}$$

$$Q = mA\sqrt{2gH} \text{ cubic feet per sec.}$$

$$\sqrt{2g} = 8.025$$

$$G = 1249.4\, m\, a \sqrt{H} \text{ gallons per hour.}$$

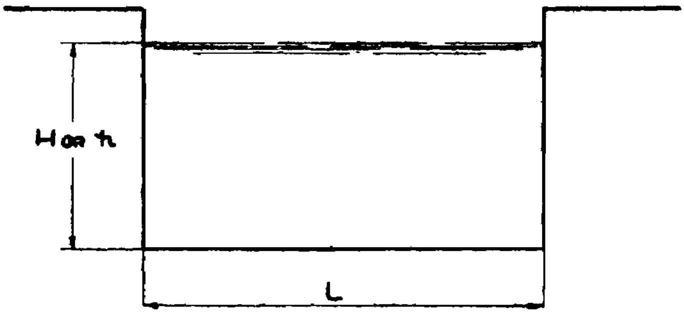
VALUES OF *m* FOR DIFFERENT ORIFICES.

Orifice in shape of vena contracta — $m = .97$
" with converging adjutage (angle 13½°) — $m = .95$
" with diverging adjutage (angle 5° 6′) — $m = .625$
" in a thin plate — $m = .611$

DISCHARGES OVER RECTANGULAR WEIRS.

Symbols used :—

H = height over still in feet.
h = " " " " inches.
Q = discharge over weir in cubic feet/second.
G = " " " " gallons/hour.
L = length of still in feet.



W. J. B. Francis's empirical formula founded on the Lowell Hydraulic Experiments,

$$Q = C\left(L - N\frac{H}{10}\right) H^{\frac{3}{2}}$$

where H = Head of water in feet.

Q = discharge in cubic feet per second

L = length of weir crest in feet.

C = 3.33 for a thin edge weir.

N = 0, 1 or 2, number of end contractions.

To apply this formula the following conditions should exist:—

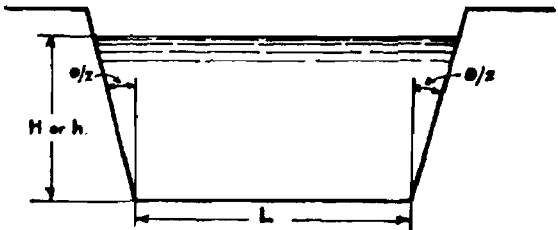
1. Head H should be between 6" and 24".
2. Depth of the leading channel should be at least 3 times the head on the weir.
3. L should be at least 3 times H.
4. Fall below the crest should not be less than half H.

DISCHARGES OVER TRAPEZOIDAL WEIRS.

DISCHARGES OVER TREPEZOIDAL WEIRS.

SYMBOLS USED:—

H = Height over sill in feet.
h = Height over sill in inches.
Q = Flow in cubic feet/second.
G = Flow in gallons/hour.
L = Length of sill in feet.
θ = 2 x angle of edge of weir = 2 x $\tan^{-1}$ slope of edge.



General Formula (Gourley & Crimp):—

$$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + 2{\cdot}48 \tan \theta/2 \times H^{2{\cdot}47}$$

$$G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 120{\cdot}1 \tan \theta/2 \times h^{2{\cdot}47}$$

Slope = tan θ/2	Formulae.
1/1	$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + 2{\cdot}48 H^{2{\cdot}47}$ $G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 120{\cdot}1 h^{2{\cdot}47}$
1/2	$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + 1{\cdot}24 H^{2{\cdot}47}$ $G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 60{\cdot}05 h^{2{\cdot}47}$
1/3	$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + {\cdot}827 H^{2{\cdot}47}$ $G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 40{\cdot}03 h^{2{\cdot}47}$
* 1/4	$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + {\cdot}62 H^{2{\cdot}47}$ $G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 30{\cdot}025 h^{2{\cdot}47}$
1/5	$Q = 3{\cdot}10 L^{1{\cdot}02} H^{1{\cdot}47} + {\cdot}496 H^{2{\cdot}47}$ $G = 1802 L^{1{\cdot}02} h^{1{\cdot}47} + 24{\cdot}02 h^{2{\cdot}47}$

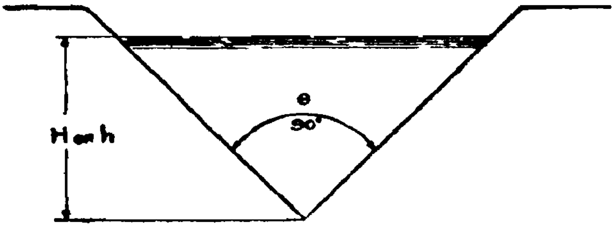
* Cippoletti Weir, the approximate formula for which is—$Q = 3{\cdot}367 L H^{1{\cdot}5}$

DISCHARGES OVER V NOTCHES.

DISCHARGES OVER V NOTCHES.

Symbols used:—

- H — height over notch in feet.
- h — " " " inches.
- Q — flow in cubic feet/second.
- G — " gallons/hour.
- θ — angle of V-notch.



Authority	General Formula.	Values of θ 90°	60°	45°	30°
Approximate	$Q = 2{\cdot}48 H^{2{\cdot}5} \times \tan \theta/2$	$2{\cdot}48 H^{2{\cdot}5}$	$1{\cdot}43 H^{2{\cdot}5}$	$1{\cdot}03 H^{2{\cdot}5}$	$\cdot 665 H^{2{\cdot}5}$
	$G = 111{\cdot}5 h^{2{\cdot}5} \times \tan \theta/2$	$111{\cdot}5 h^{2{\cdot}5}$	$64{\cdot}4 h^{2{\cdot}5}$	$46{\cdot}2 h^{2{\cdot}5}$	$29{\cdot}9 h^{2{\cdot}5}$
Gourley and Crimp	$Q = 2{\cdot}48 H^{2{\cdot}47} \times \tan \theta/2$	$2{\cdot}48 H^{2{\cdot}47}$	$1{\cdot}432 H^{2{\cdot}47}$	$1{\cdot}037 H^{2{\cdot}47}$	$\cdot 6645 H^{2{\cdot}47}$
	$G = 120{\cdot}1 h^{2{\cdot}47} \times \tan \theta/2$	$120{\cdot}1 h^{2{\cdot}47}$	$69{\cdot}34 h^{2{\cdot}47}$	$49{\cdot}74 h^{2{\cdot}47}$	$32{\cdot}17 h^{2{\cdot}47}$
Barnes	$Q = 2{\cdot}462 H^{2{\cdot}48} \times Z$	$2{\cdot}48 H^{2{\cdot}48}$	$1{\cdot}435 H^{2{\cdot}48}$	$1{\cdot}032 H^{2{\cdot}48}$	$0{\cdot}669 H^{2{\cdot}48}$
	$G = 116{\cdot}3 h^{2{\cdot}48} \times Z$	$117{\cdot}1 h^{2{\cdot}48}$	$67{\cdot}8 h^{2{\cdot}48}$	$48{\cdot}73 h^{2{\cdot}48}$	$31{\cdot}61 h^{2{\cdot}48}$

Where $Z = \tan \theta/2 / (\tfrac{1}{2} \sin \theta/2)^{\cdot[illegible]}$

The triangular notch:—The formula largely used is that given by Prof. James Thompson, namely:—

$$Q = CH^{\frac{5}{2}}$$

where Q = discharge in cubic feet per minute.
H = Head in inches or the depth in inches of the crest of the notch, below the still water in the pool.

C = the empirical coefficient. The average value of C given by the Prof. Thompson for heads ranging from 2" to 7" was 0.305, and C is not a constant quantity so that his formula is Q = 0.305 $H^{\frac{5}{2}}$ but is found to diminish slightly as the head increases. The table by J. Barr; James Watt; Engineering Laboratories, Glasgow is given as under:—

V notch is used in filtering plants in Poona.

Flow of water per minutes through 90° V notch.

Head in Inches.	Value of Coefficient	Flow in Cubic feet.	Flow in gallons.
2″	.3104	1.755	10.94
2½″	.3084	3.045	18.97
3″	.3068	4.782	29.79
3½″	.3057	7.002	43.63
4″	.3047	9.75	60.74
4½″	.3038	13.05	81.29
5″	.3032	16.95	105.6
5½″	.3026	21.46	133.7
6″	.3021	26.63	166.0
6½″	.3017	32.49	202.4
7″	.3013	39.05	243.0
7½″	.3009	46.34	288.7
8″	.3006	54.06	338.9
8½″	.3003	62.92	392.0
9″	.3000	72.9	454.2
10″	.2995	94.7	590.0
9½″	.2999	83.33	519.2

Delivery of weirs:—

General remarks:—For comparatively small flows, which do not vary greatly in quantity, submerged circular orifice is the best with a small fall available; it is impracticable usually to use a submerged orifice.

Rectangular weir: With this weir, the discharge varies roughly, as $H^{3/2}$ and with the triangular notch varies as $H^{5/2}$, where H = head. Therefore, for equal heads, it is necessary to measure the head more exactly in the case of the triangular notch, but for the same discharge, the head over the triangular notch is considerably greater than over the rectangular weir, which diminishes the percent error in its estimation.

THEORETICAL H.P. OF A FALL OF WATER.

Q = volume of flowing water in cubic ft. per sec.
H = head or fall of water in ft.
H.P. = horse power (550 foot pounds per sec.).

$$H.P. = .11322\ QH$$

RESISTANCE IN FITTINGS.

Equivalent length of straight pipe of same diameter which would cause the same friction as the resistance in fittings.

Foot Valve and Strainer	15	yards.
Sluice Valve full open	½	"
Back Pressure Valve with hinged flap.	3½	"
Back Pressure Valve—Globe Type ..	45	"
Bends (radius 3 to 5 diameters) ..	1	"
Round Elbows	3	"
Sharp Elbows and Tees	6	"

RECTANGULAR TANKS.

No. of gallons contained } = Length × breadth × depth (in feet) × 6.23.

CIRCULAR TANKS.

$$\text{Area in square feet} = \frac{\text{Gallons}}{\text{depth in feet} \times 6.23}$$

WEIGHTS OF PIPES.

WEIGHT OF CAST IRON PIPES.

Rule for finding the weight of cast iron pipes,

D = outside diameter in inches.
d = inside " " "
W = weight of 1 yard of pipe in lbs.

$$W = 7.35 \ (D^2 - d^2)$$

The weight of two flanges = weight of about 1 foot of pipe.

To find the weight of water in any large water tank in tons, when full:—Reduce the contents to cubic feet, and divide by 36 ft. tons weight. Thus in a tank 20 ft. x 12 ft. x 6 ft. = 1440 cubic feet.

$$\frac{1440}{36} = 40 \text{ tons of water when full.}$$

Weight of W. I. pipe, 1 foot long.

Inch	Lbs.	Threads
½"	7/8	14
¾"	1¼	14
1"	1⅝	11
1¼"	2⅝	11
1½"	$2\frac{15}{16}$	11
2"	3¾	11

VELOCITY AND DISCHARGE UNDER A GIVEN HEAD.

Where V = velocity of flow in feet per sound under a head of H feet of liquid

$g = 32.2.$

$$V = \sqrt{2g\ H.} = 8.025\sqrt{H.}$$

$$H = \frac{V^2}{2g} = .0155V^2.$$

THEORETICAL VELOCITY OF WATER DUE TO HEAD.

Head in feet.	Velocity Feet per Sec.
1	8·025
2	11·35
3	13·90
4	16·05
5	17·94
6	19·66
7	21·23
8	22·70
9	24·07
10	25·37
15	31·08
20	35·89
30	43·95
40	50·75
50	56·75
100	80·25

FLUID FRICTION IN PIPES.

Mr. Thomas Box gives in his hydraulic tables the following formulæ to determine the loss of head by friction in pipes.

$$H = \frac{G^2 \times L}{(3\,D)^5}$$

In which D = diameter of pipe in inches.

G = gallons per minute.

H = head of water in feet.

L = length of pipe in yards.

USUAL INCLINATION OF PIPES, &c.

1	inch in	12	feet	=	minimum fall for house drains.
1	„	100	„	=	„ „ main drains from houses.
1	„	250	„	=	fall of rivers and rapid currents.
1	„	350	„	=	„ ordinary rivers.
1	„	500	„	=	„ water channels, supply pipes to reservoirs and small canals.
1	„	1000	„	=	very slow current, almost stagnant.

To find the inclination of pipes in feet per mile to overcome friction.

$$\text{Inclination} = \frac{V^2 \times 2{\cdot}3}{D},$$ where V = velocity in ft. per secon.

D=diameter of pipe in feet.

Velocity in water mains 3′ per second.

Velocity in pumping mains 3′ to 5′ per second.

Rough rule for inclination of house drains, etc.

Diameter in inches×10=length in feet in which a fall of 1 foot occurs.

Example : 6-inch diameter pipe—inclination 1 in 60.

EQUIVALENT PIPES.

To find how many pipes of one diameter it will take to discharge same quantity as one large pipe.

$$\text{Number required} = \frac{\sqrt{P^5}}{\sqrt{p^5}}$$

Where P is diam of large pipe in inches, and p of small pipe in inches.

Hints for installing and running centrifugal pumps.

1. Suction lift should not exceed 15 ft.
2. Velocity of water through the foot valve to vary from 6 to 8 feet per second (valves from 6" to 14").
3. Sluice valve is required instead of foot valve if water is to be pumped under pressure.
4. Valves must not be fixed on the balance pipe.
5. The grease used should be clear and free from grit.
6. Sluice valve on suction side must be fully open before suctioning.
7. To run the pump see that it is solidly primed with water up to the delivery valve to avoid pumping troubles.

———:o:———

NOMOGRAMS.

Explanation.—Given any two of three variables in each of the succeeding formulae—place a straight edge across the corresponding points on the respective scales for the two known variables, and read the value of the third variable at the point of intersection of the straight edge with the other scale.

Example (I) FLOW IN NEW ASPHALTED C.I. PIPES. (See page 283).

48″ dia. pipe. Gradient 1 in 500. Required—velocity.

Straight line through 48″ on dia. scale and 500 on L|H scale cuts velocity scale at 6.45 ft.|sec.

Example (II) PIPE VELOCITY. (See page 284).

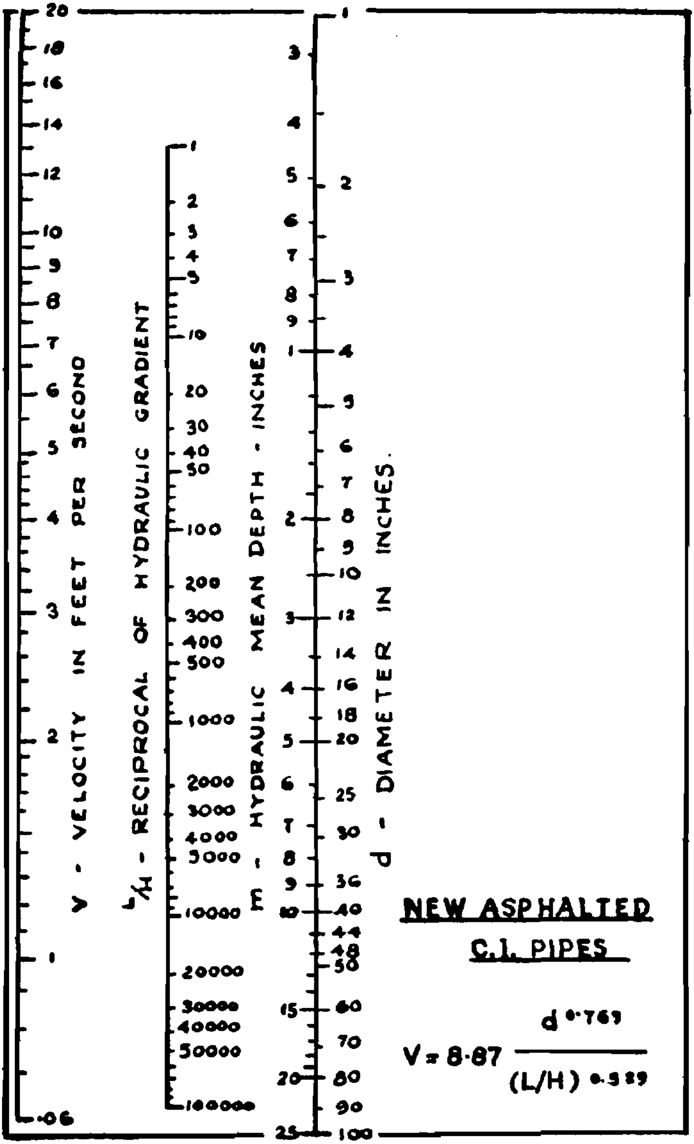
100,000 G.P.H. in a 24″ dia. main. Required—velocity.

Straight line through 100,000 G. P. H. on flow scale and 24″ on pipe dia. scale cuts velosity scale at 1.4 ft.|sec.

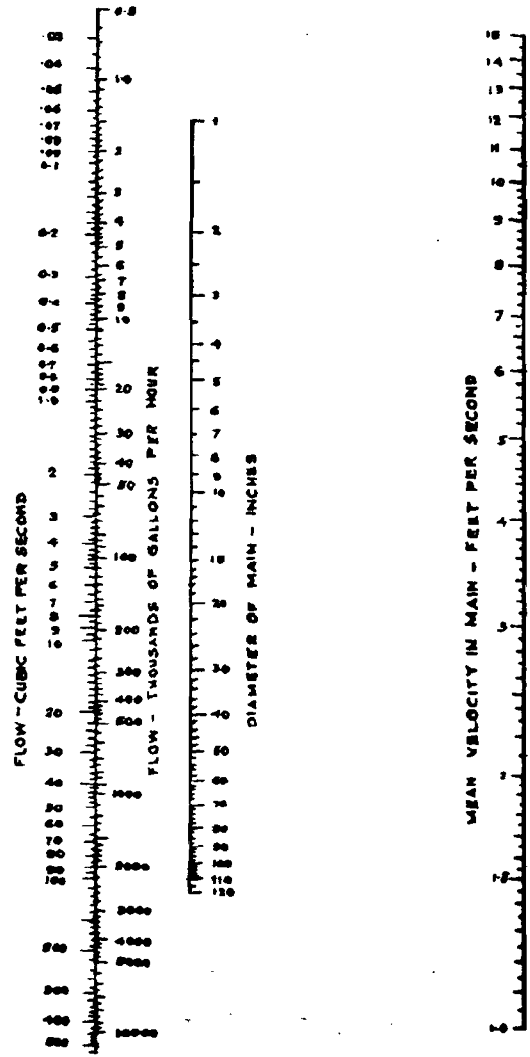
Example (III) FLOW IN NEW UNCOATED C.I. PIPES. (See page 285).

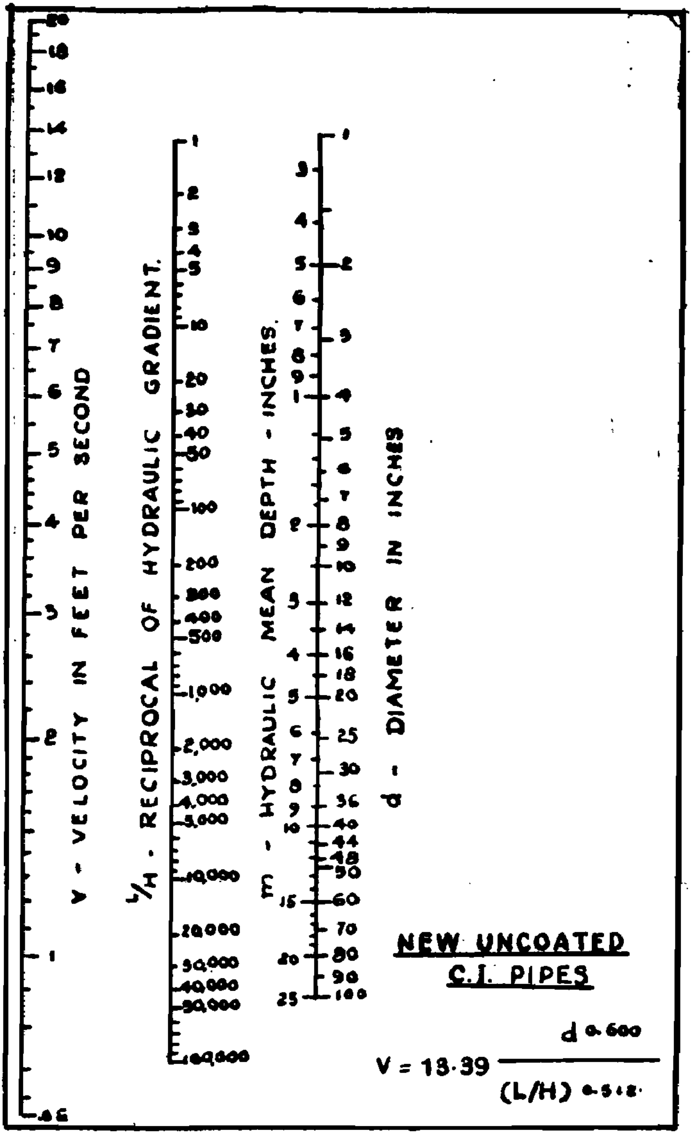
48″ dia. pipe—velocity 3.6 ft.|sec. Required—hydraulic gradient.

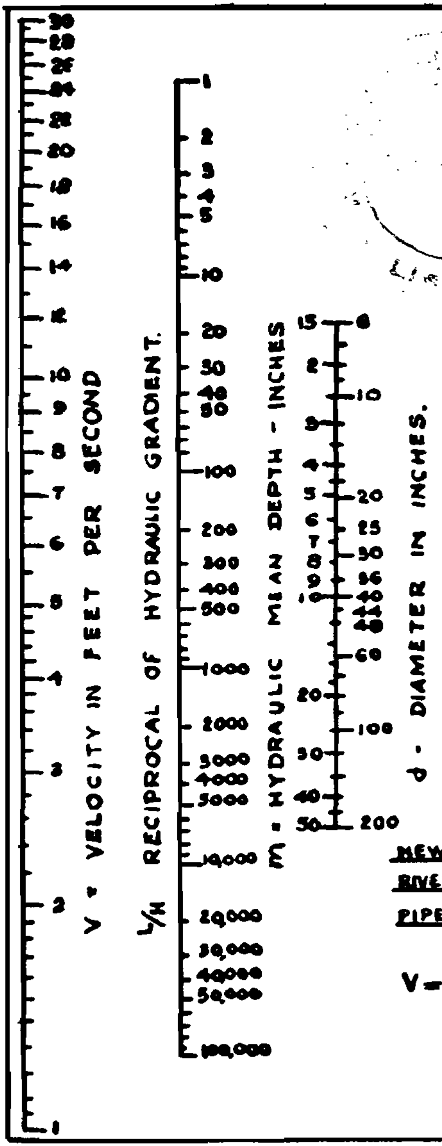
Straight line through 48″ on dia. scale and 3.6 on velocity scale cuts L|H scale at 1200. Hence gradient is 1 in 1200.


V - VELOCITY IN FEET PER SECOND
L/H - RECIPROCAL OF HYDRAULIC GRADIENT
m - HYDRAULIC MEAN DEPTH - INCHES
d - DIAMETER IN INCHES
NEW ASPHALTED C.I. PIPES
V = 8·87 d^0·769 / (L/H)^0·529

PIPE VELOCITY CHART.

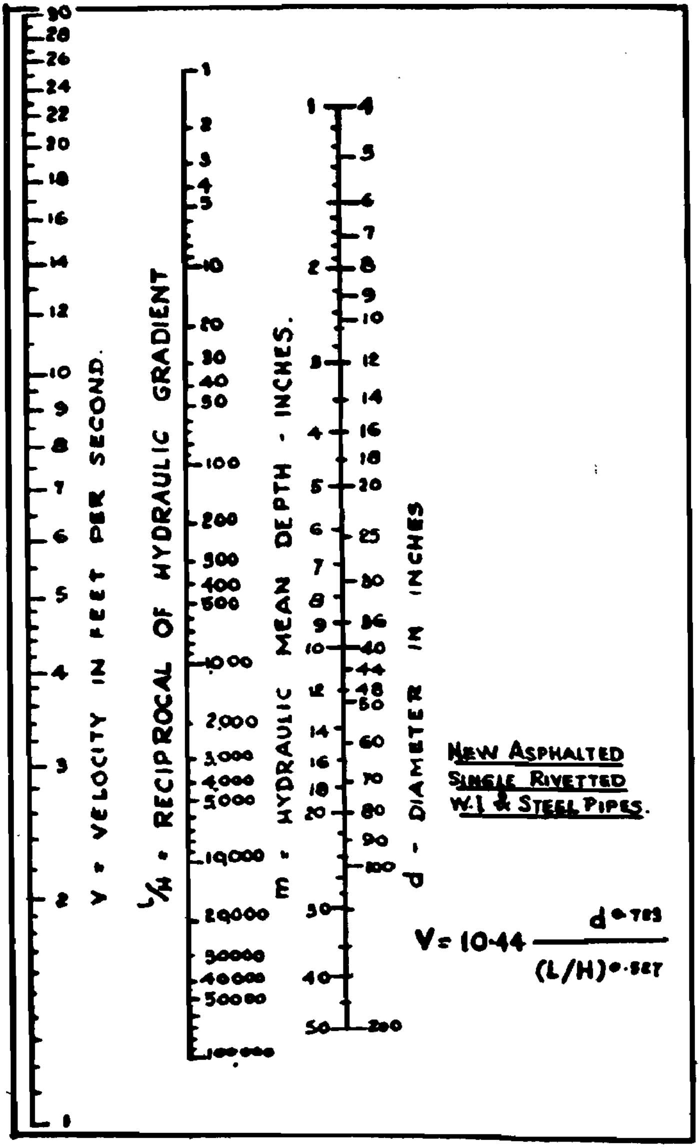


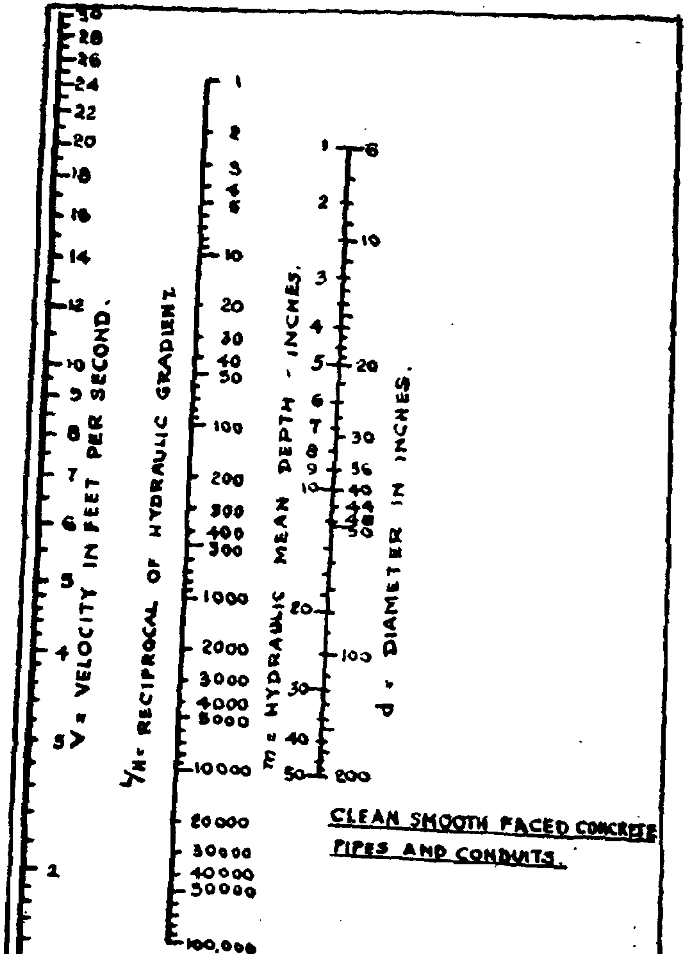

V - VELOCITY IN FEET PER SECOND
L/H - RECIPROCAL OF HYDRAULIC GRADIENT.
m - HYDRAULIC MEAN DEPTH - INCHES.
d - DIAMETER IN INCHES
NEW UNCOATED C.I. PIPES
V = 13·39 d^0·600 / (L/H)^0·518



NEW ASPHALTED DOUBLE RIVETTED W.I. AND STEEL PIPES.

$$V = 23{\cdot}65 \frac{d^{0{\cdot}440}}{(L/H)^{0{\cdot}520}}$$


V = VELOCITY IN FEET PER SECOND.
L/H = RECIPROCAL OF HYDRAULIC GRADIENT
m = HYDRAULIC MEAN DEPTH - INCHES.
d - DIAMETER IN INCHES
NEW ASPHALTED
SINGLE RIVETTED
W.I & STEEL PIPES.



$$V = 10{\cdot}59 \frac{d^{0{\cdot}567}}{(L/H)^{0{\cdot}471}} = 25{\cdot}24 \frac{m^{0{\cdot}567}}{(L/H)^{0{\cdot}471}}$$

WATER SUPPLY ENGINEERING

(THEORY & PRACTICE)

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WITH A FOREWARD BY

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Published by E. J. Umrigar, The Tata Hydro-Electric Power Supply Cos., Ltd., Bombay House, 24, Bruce Street, Fort, Bombay 1, and printed by J. J. Khambatta at the "Jam-e-Jamshed" Press, Ballard House, Mangalore Street, Fort, Bombay.

PREFACE

The object of this book is to meet with the present day growing demands of Water Engineers, Overseers and Inspectors employed in the Water Dept. of the Municipality. The subjects covered in this book are varied and numerous such as design of the water supply system, distribution system, detection and public water prevention of wastage of water supply, masonry and earthen dams, scraping of mains, water supply through bore wells, infiltration galleries, calculations of flow of water through 'V' and rectangular notches, hydraulic datas and memoranda etc. Details of each chapter have been collected and expressed from several years, experience of the authors and they are indeed indebted to Water Engineers and others of various Towns of India, who have allowed reproductions of illustrations to be published in this book and also express sincere thanks to those gentlemen who have permitted references for their formulas and tables etc. and also to those who have in various other ways aided in the preparation of this work, especially to Mr. C. W. Casse., M.I.C.E., M.I. Mech. E., M.I.E.E., and Mr. D. H. Howell., M.I.C.E., of Lahore, and others.

The Authors feel confident that this short treatise will be of service to those interested in laying out and designing the water supply system as well as to students, and candidates for this sort of work.

For any corrections and suggestions for improvements the authors shall be grateful.

April 1950 — E. J. UMRIGAR.

Bombay. — M. N. CHINOY.

FOREWORD

The one thing which makes it possible for more than a few hundred people to live together in a town or city, is an adequate supply of pure water. If reasonably healthy and comfortable conditions are to be maintained, the supply of water must be continuously available and we must be absolutely certain that as far as human care can assure it, the supply will always be free from those water-borne diseases which can affect a whole community in a few weeks and cause untold suffering.

Where, as in some fortunate places, there has been this constant supply of pure water for a very long time the inhabitants are inclined to regard it as much a matter of course as the supply of air which they breathe, but less fortunate people or people in places where owing to some accident the supply has broken down, know that the supply of water can make the difference between comfort and misery.

It follows that Water Engineering is one of the essentials of civilisation and the proper training of those engaged in it, of paramount importance. It is therefore somewhat surprising to find the number of books devoted to this specialised branch of engineering to be far from extensive and a new book is always welcome.

Messrs. Umrigar and Chinoy have produced a book which should take a worthwhile place in the literature of their subject so far as all English-speak-

ing people are concerned, but their special knowledge of conditions in India has enabled them to write a book of special value to that great country.

Although the writer has no first-hand knowledge of conditions in India, he has read with interest a book in which one of his old students has taken an important part and hopes that the sound ideas put forward in this book will make an important contribution to advancing the comfort and health of the Indian peoples.

10th February, 1950.

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"Water Supply Engineering"

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WATER SUPPLY FOR A TOWN

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